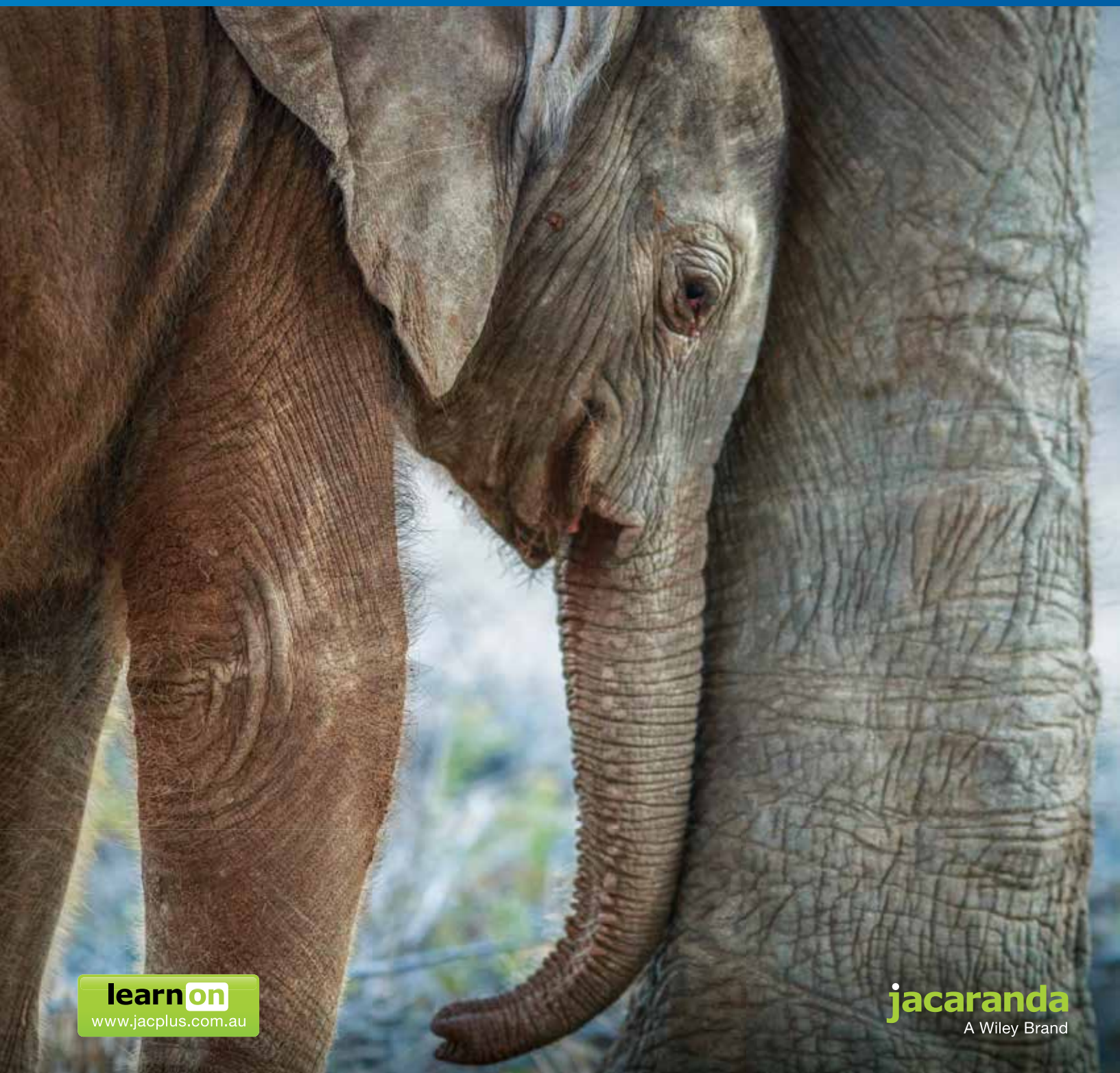
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CORE SCIENCE 4

NSW AUSTRALIAN CURRICULUM SCIENCE | SECOND EDITION

STAGE



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PAUL ARENA | PASCALE WARNANT | KAHNI BURROWS
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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

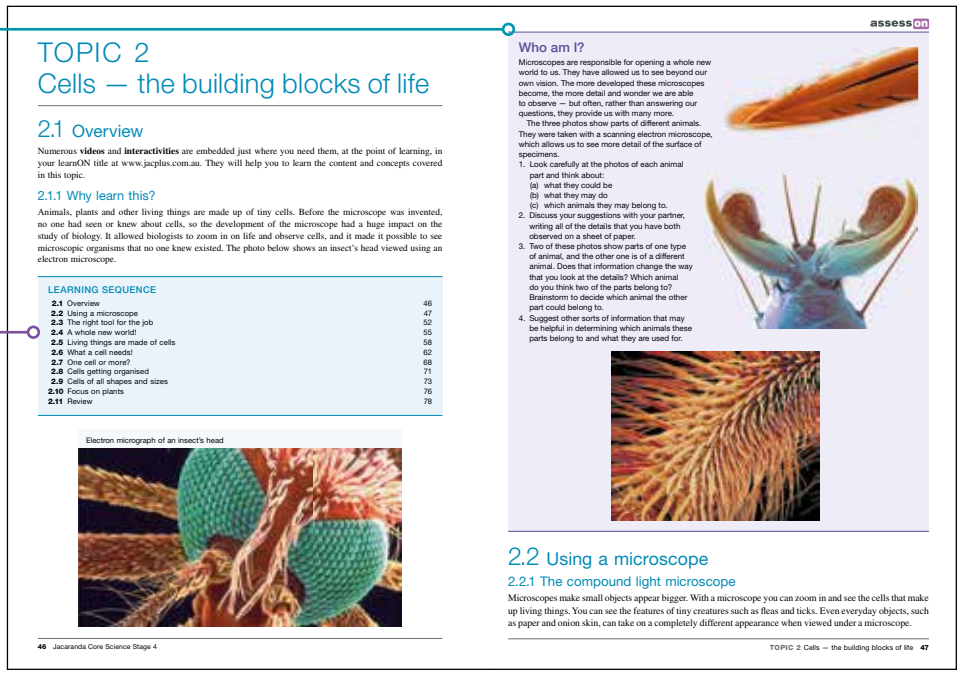
The *Core Science Stage 4* textbook and learnON are designed for students who come to the science classroom with a range of interests, backgrounds and learning styles. The topic units provide an in-depth coverage of essential and additional syllabus content.

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



TOPIC 2
Cells — the building blocks of life

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?

Animals, plants and other living things are made up of tiny cells. Before the microscope was invented, no one had seen or knew about cells, so the development of the microscope had a huge impact on the study of biology. It allowed biologists to zoom in on life and observe cells, and it made it possible to see microscopic organisms that no one knew existed. The photo below shows an insect's head viewed using an electron microscope.

LEARNING SEQUENCE

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Electron micrograph of an insect's head

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assessON

Who am I?

Microscopes are responsible for opening a whole new world to us. They have allowed us to see beyond our own vision. The more developed these microscopes become, the more detail and wonder we are able to observe — but often, rather than answering our questions, they provide us with many more.

The three photos show parts of different animals. They were taken with a scanning electron microscope, which allows us to see more detail of the surface of specimens.

1. Look carefully at the photos of each animal part and think about:
   (a) what they could be
   (b) what they may do
   (c) which animals they may belong to.
2. Discuss your suggestions with your partner, writing all of the details that you have both observed on a sheet of paper.
3. Two of these photos show parts of one type of animal, and the other one is of a different animal. Does that information change the way that you look at the details? Which animal do you think two of the parts belong to? Brainstorm to decide which animal the other part could belong to.
4. Suggest other sorts of information that may be helpful in determining which animals these parts belong to and what they are used for.

2.2 Using a microscope

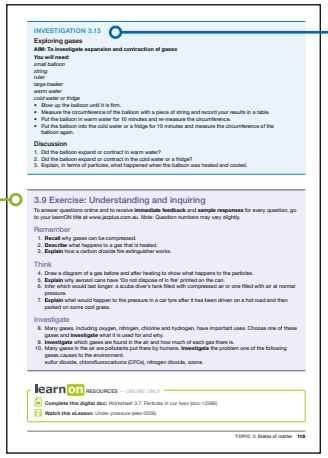
2.2.1 The compound light microscope

Microscopes make small objects appear bigger. With a microscope you can zoom in and see the cells that make up living things. You can see the features of tiny creatures such as fleas and ticks. Even everyday objects, such as paper and onion skin, can take on a completely different appearance when viewed under a microscope.

TOPIC 2 Cells — the building blocks of life 47

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 4 students.



INVESTIGATION 3.13

Exploring gases

AIM: To investigate expansion and contraction of gases

You will need:
small balloon
string
ruler
large beaker
warm water
cold water or fridge

- Blow up the balloon until it is firm.
- Measure the circumference of the balloon with a piece of string and record your results in a table.
- Put the balloon in warm water for 10 minutes and re-measure the circumference.
- Put the balloon into the cold water or a fridge for 10 minutes and measure the circumference of the balloon again.

Discussion

1. Did the balloon expand or contract in warm water?
2. Did the balloon expand or contract in the cold water or a fridge?
3. Explain, in terms of particles, what happened when the balloon was heated and cooled.

3.9 Exercise: Understanding and inquiring

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. Alobe Question numbers may vary slightly.

Remember

1. **Recall** why gases can be compressed.
2. **Describe** what happens to a gas that is heated.
3. **Explain** how a carbon dioxide fire extinguisher works.

Think

4. Draw a diagram of a gas before and after heating to show what happens to the particles.
5. **Explain** why aerosol cans have 'Do not dispose of in fire' printed on the can.
6. Infer which would last longer: a scuba diver's tank filled with compressed air or one filled with air at normal pressure.
7. **Explain** what would happen to the pressure in a car tyre after it has been driven on a hot road and then parked on some cool grass.

Investigate

8. Many gases, including oxygen, nitrogen, chlorine and hydrogen, have important uses. Choose one of these gases and **investigate** what it is used for and why.
9. **Investigate** which gases are found in the air and how much of each gas there is.
10. Many gases in the air are pollutants put there by humans. **Investigate** the problem one of the following gases causes to the environment.
    sulfur dioxide, chlorofluorocarbons (CFCs), nitrogen dioxide, ozone

learnON RESOURCES — ONLINE ONLY

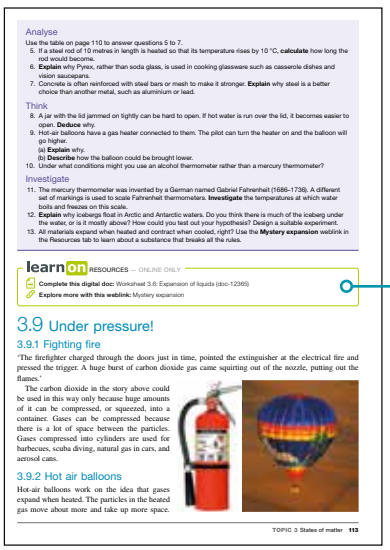
Complete this digital doc: Worksheet 3.7: Particles in our lives (doc-12390)

Watch this eLesson: Under pressure (eles-0058)

TOPIC 3 States of matter 113

Investigations in each chapter reinforce the topic concepts and provide a comprehensive practical program for stage 4 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.



Analyse

Use the table on page 110 to answer questions 5 to 7.

5. If a steel rod of 10 metres in length is heated so that its temperature rises by 10 °C, **calculate** how long the rod would become.
6. **Explain** why Pyrex, rather than soda glass, is used in cooking glassware such as casserole dishes and vision saucepans.
7. Concrete is often reinforced with steel bars or mesh to make it stronger. **Explain** why steel is a better choice than another metal, such as aluminium or lead.

Think

8. A jar with the lid jammed on tightly can be hard to open. If hot water is run over the lid, it becomes easier to open. **Deduce** why.
9. Hot-air balloons have a gas heater connected to them. The pilot can turn the heater on and the balloon will go higher.
   (a) **Explain** why.
   (b) **Describe** how the balloon could be brought lower.
10. Under what conditions might you use an alcohol thermometer rather than a mercury thermometer?

Investigate

11. The mercury thermometer was invented by a German named Gabriel Fahrenheit (1686–1736). A different set of markings is used to scale Fahrenheit thermometers. **Investigate** the temperatures at which water boils and freezes on this scale.
12. **Explain** why icebergs float in Arctic and Antarctic waters. Do you think there is much of the iceberg under the water, or is it mostly above? How could you test out your hypothesis? Design a suitable experiment.
13. All materials expand when heated and contract when cooled, right? Use the **Mystery expansion** weblink in the Resources tab to learn about a substance that breaks all the rules.

learnON RESOURCES — ONLINE ONLY

Complete this digital doc: Worksheet 3.6: Expansion of liquids (doc-12365)

Explore more with this weblink: Mystery expansion

3.9 Under pressure!

3.9.1 Fighting fire

'The firefighter charged through the doors just in time, pointed the extinguisher at the electrical fire and pressed the trigger. A huge burst of carbon dioxide gas came squirting out of the nozzle, putting out the flames.'

The carbon dioxide in the story above could be used in this way only because huge amounts of it can be compressed, or squeezed, into a container. Gases can be compressed because there is a lot of space between the particles. Gases compressed into cylinders are used for barbecues, scuba diving, natural gas in cars, and aerosol cans.

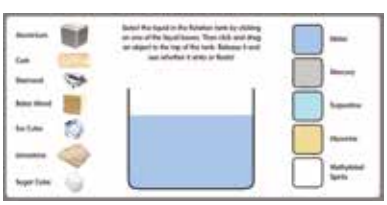
3.9.2 Hot air balloons

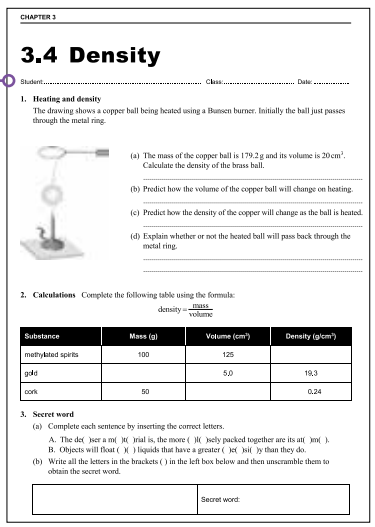
Hot-air balloons work on the idea that gases expand when heated. The particles in the heated gas move about more and take up more space.

TOPIC 3 States of matter 113

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







CHAPTER 3

3.4 Density

Student: ..... Class: ..... Date: .....

1. **Heating and density**

The drawing shows a copper ball being heated using a Bunsen burner. Initially the ball just passes through the metal ring.

(a) The mass of the copper ball is 179.2 g and its volume is 20 cm³. Calculate the density of the brass ball.

(b) Predict how the volume of the copper ball will change on heating.

(c) Predict how the density of the copper will change as the ball is heated.

(d) Explain whether or not the heated ball will pass back through the metal ring.

2. **Calculations** Complete the following table using the formula:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Substance	Mass (g)	Volume (cm³)	Density (g/cm³)
methylated spirits	100	125	
gold		5,0	19,3
cork	50		0,24

3. **Secret word**

(a) Complete each sentence by inserting the correct letters.

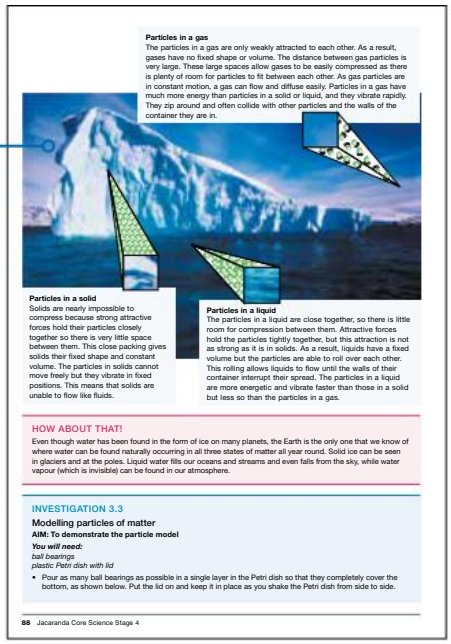
A. The de( )ser a ro( )( )rial is, the more ( )( )sely packed together are its at( )m( ).

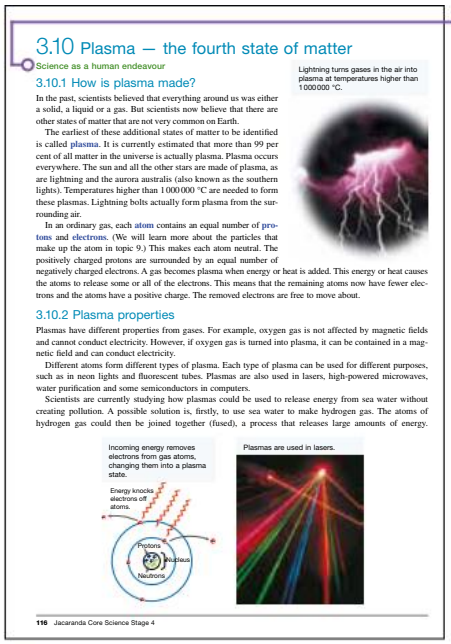
B. Objects will float ( )( ) liquids that have a greater ( )e( )si( )y than they do.

(b) Write all the letters in the brackets ( ) in the left box below and then unscramble them to obtain the secret word.

Secret word:

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



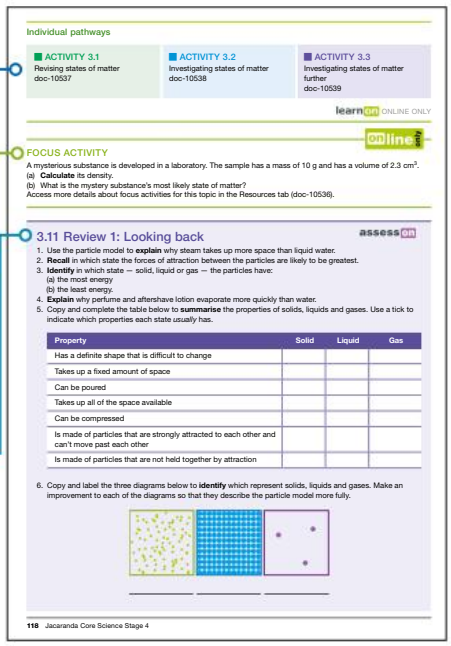


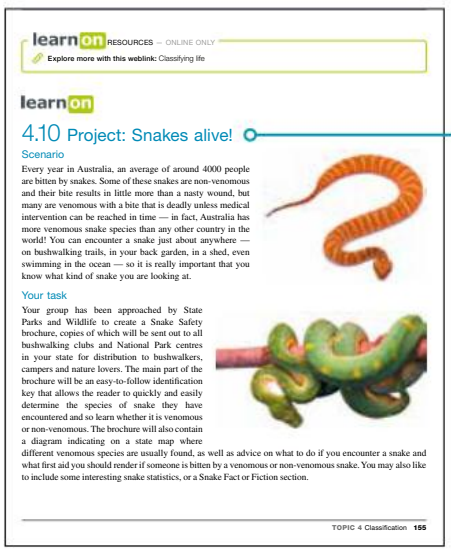
Science as a human endeavour units in each chapter provide high-interest content that explicitly links particular areas of the NSW Australian curriculum Science syllabus.

Individual pathways chapter revision Word documents at three differentiated levels.

Focus activities provide revision for each chapter.

Looking back spreads provide a range of chapter review activities.



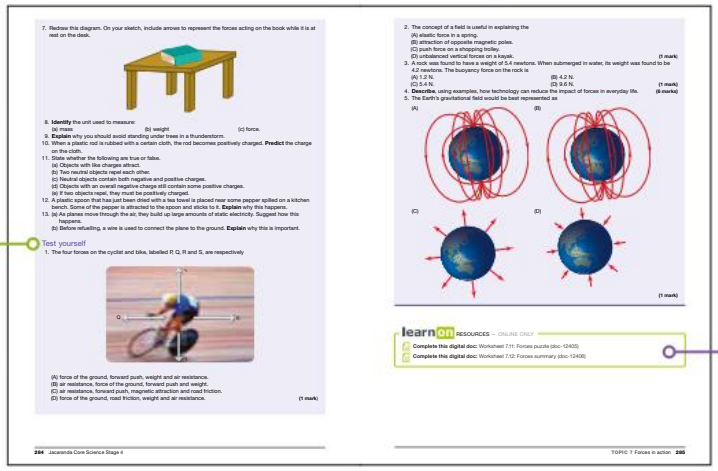


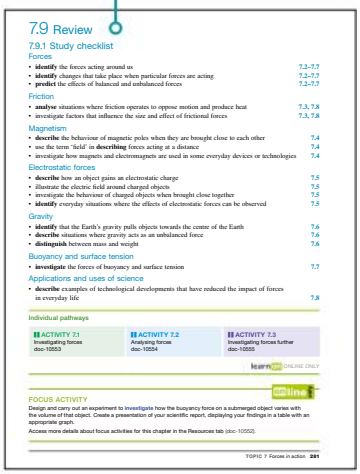
ProjectsPLUS Some topics include a Project, resources for this can be found in the Resources tab.

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.





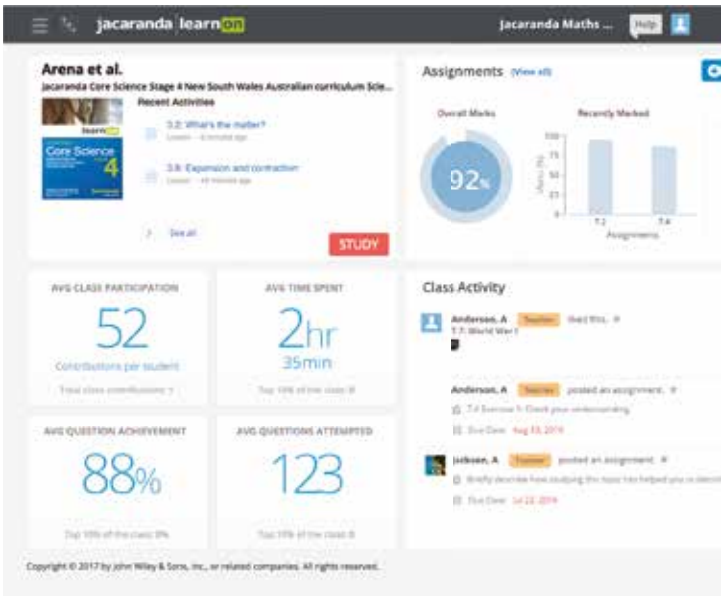
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Core Science contains a free activation code for *learnON* (please see instructions on the inside front cover), so students and teachers can take advantage of the benefits of both print and digital, and see how *learnON* enhances their digital learning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

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?

The word 'science' comes from the Latin word *scientia*, meaning knowledge. Scientists have been seeking knowledge for many thousands of years. Before the 1600s, early scientists were often called philosophers; because they had limited technology to investigate the world around them, they merely applied their reasoning to make sense of what they saw.

Today, scientists use sophisticated equipment to carry out investigations and build on the body of knowledge that is science. But science is more than a collection of important facts. It is about exploring and, as an explorer, you will be trained to investigate scientifically so the conclusions you arrive at are based on sound logic and supported by evidence.

Forensic scientists use their knowledge to help solve crimes.

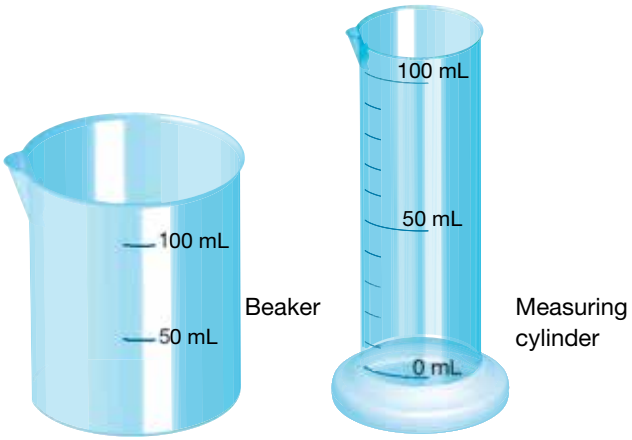


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1.1.2 Thinking about investigating

1. Look around the laboratory. Identify five features special to this working environment.
2. Identify five everyday devices that have been invented with the assistance of science.
3. Do you know anyone working in science? Describe what they do.
4. Think of a really important scientific discovery. Discuss with a partner why you think it is so significant.
5. These two pieces of equipment are used for measuring volumes of liquids.



Identify an important difference between them, other than their shape. Outline when each should be used.

6. Some of the skills that scientists use are the same as those used by detectives in solving a crime. Careful observations are required before any conclusions can be drawn. Look carefully at the drawing at right and describe what you think has happened.
7. If you were asked to draw a picture of a scientist, what would you draw? Draw your image of a scientist on A4 paper. Underneath your drawing, write a brief description of the scientist.



INVESTIGATION 1.1

Design and separate

AIM: To separate the four components of a mixture of 'dead' matches, pebbles, metal paperclips and sand

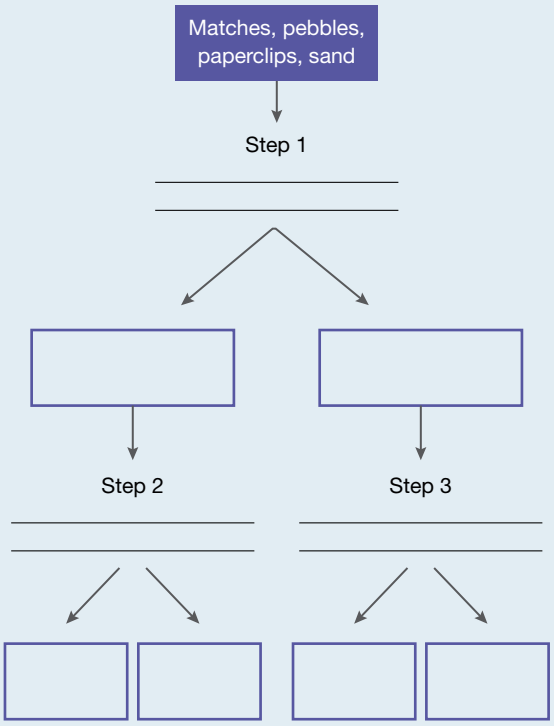
You will need:

sand (about 250 mL)
'dead' matches
small pebbles
metal paperclips
plastic container (about 500 mL)
A3 paper
other equipment and water as required

- Mix the sand, matches, pebbles and paperclips evenly in a plastic container.
- Devise and write a step-by-step plan to separate the four components. You will need to think about the features of each part of the mixture that will make separation possible.
- Make a list of all of the equipment that you will need.
- Gather the equipment and perform the separation.

Discussion

1. Copy and complete the following flow chart in your notebook. Outline each step you followed and, in each of the boxes, list the items separated.



2. Identify the unique property or feature of each item that allowed it to be separated from the other items.

1.2 What do scientists do?

Science as a human endeavour

1.2.1 The disciplines of science

You can find **scientists** just about anywhere. They could be in a desert finding out how plants survive without water. They could be digging deep into the ice in Antarctica. You might find a scientist searching for fossils on a rocky shore, counting rare animals in a rainforest or monitoring electricity in a power station. Some scientists work in laboratories, searching for a cure for a disease. Others work in the chemical industry. You might even find a scientist in space.

There are many disciplines of study in science. A few are shown on these pages.

HOW ABOUT THAT!

Not all scientists were high achievers at school. Some very famous scientists were average or below average school students. Albert Einstein is probably the most famous example. He did not talk until he was three years old. He left school at the age of 15 and went back later. He passed his university exams by studying the notes of his classmates.



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Earth science Earth scientists, or geologists, study the Earth. They investigate how rocks and mountains form. Some specialised geologists, called seismologists, study earthquakes. Palaeontologists study fossils and ancient rocks. Vulcanologists study volcanoes.



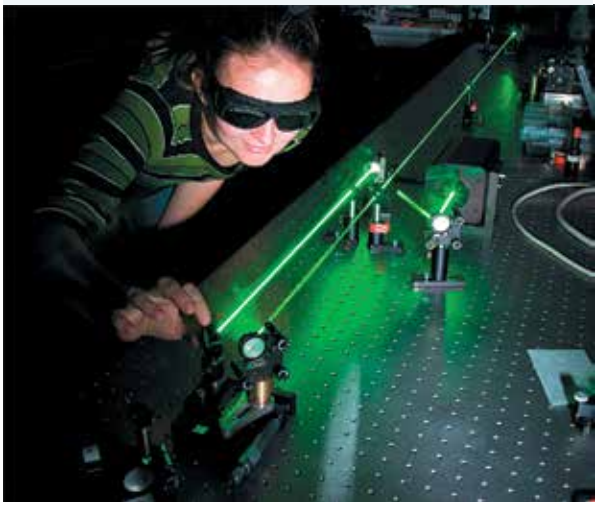
Biology Biologists study living things. They investigate how living things function and how they interact. Some biologists, such as botanists and horticulturists, study plants. Zoologists and veterinarians study animals. Microbiologists study microscopic living things. People like doctors and dentists use their knowledge of biology to help keep people and their teeth healthy.



Psychology Psychology is the study of human behaviour. Psychologists study the causes of behaviour, including the emotional, social and developmental factors involved. In general, psychology is concerned with how people perceive the world around them and how they react to it, how they learn and how they relate to others and function in groups.



Physics Physicists study different types of energy. They investigate and explain things like movement, heat, nuclear energy, light and electricity. Some engineers use their knowledge of physics to make sure buildings are strong and cars are safe. A knowledge of physics is also used in electronics, computer design and even special effects in movies.



Astronomy Astronomers study the night sky. They are concerned with planets, moons, stars, comets and other objects in space.



Chemistry Chemists study how substances react with each other. They investigate and explain why some substances behave differently from others and how they can best be used. Industrial chemists might look for ways to make better paints or plastics. Pharmacists are chemists too. They work with chemicals that are used to treat illness and disease.



1.2.2 A mix of science

The boundaries between the different sciences are often crossed. Biophysicists and biochemists work in more than one field. Scientists from different fields often work together to solve problems. **Physicists** work with medical staff to develop the bionic ear. Physicists and **geologists** work together to locate underground mineral deposits using soundwaves. **Chemists** work with **biologists** to develop medicines such as antibiotics.

Specialising

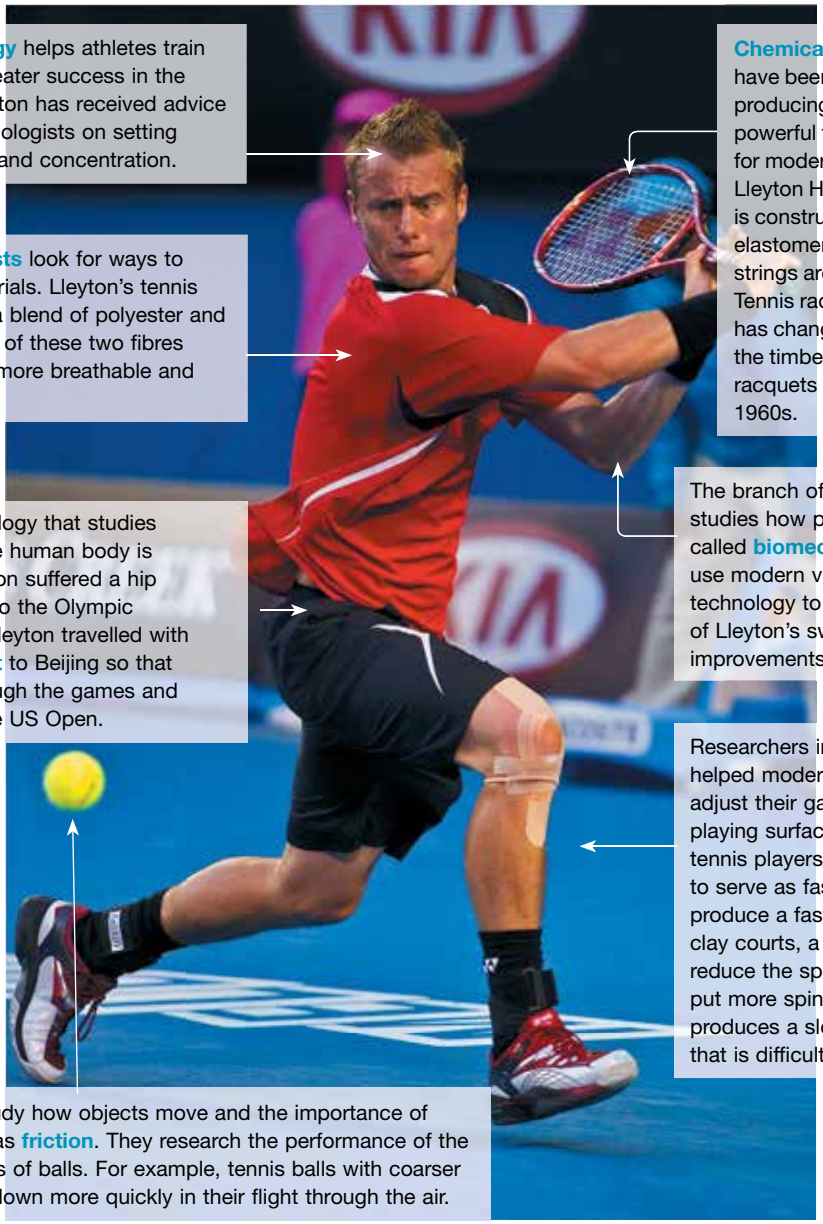
Within each discipline of science, scientists specialise in a specific area. For example, in psychology, **neuropsychologists** study the different areas of the brain to better understand brain functions such as memory and learning. **Sports psychologists** advise athletes on self-image and on maintaining the motivation to persist and succeed in their chosen sport.

Science and technology

Scientific discoveries have helped improve our quality of life. Whenever you turn on a light, fly in a plane, play tennis or flush a toilet, you are using a product of scientific knowledge. The term 'technology' refers to devices that use scientific ideas to make life easier.

Some scientific discoveries happen by accident. Bacteriologist Alexander Fleming discovered the first antibiotic, which he called penicillin. He observed that a tiny piece of mould that had fallen into his experiment stopped the growth of bacteria.





Sports psychology helps athletes train their minds for greater success in the sports arena. Lleyton has received advice from sports psychologists on setting goals, motivation and concentration.

Industrial chemists look for ways to make better materials. Lleyton's tennis outfit is made of a blend of polyester and cotton. The blend of these two fibres makes the fabric more breathable and durable.

The branch of biology that studies the function of the human body is **physiology**. Lleyton suffered a hip injury leading up to the Olympic Games in 2008. Lleyton travelled with a **physiotherapist** to Beijing so that he could get through the games and continue on to the US Open.

Chemical engineers have been responsible for producing a lightweight but powerful tennis racquet for modern tennis players. Lleyton Hewitt's racquet frame is constructed of graphite, elastomer and Kevlar. The strings are made of nylon. Tennis racquet technology has changed greatly from the timber and catgut tennis racquets of the 1950s and the 1960s.

The branch of physics that studies how people move is called **biomechanics**. Scientists use modern video and computer technology to analyse every part of Lleyton's swing to help suggest improvements.

Researchers in physics have helped modern tennis players adjust their game to suit different playing surfaces. On a grass court, tennis players are encouraged to serve as fast as possible to produce a fast, low bounce. On clay courts, a player needs to reduce the speed of the serve and put more spin on the ball. This produces a slower, higher bounce that is difficult to return.

Physicists study how objects move and the importance of **forces** such as **friction**. They research the performance of the different types of balls. For example, tennis balls with coarser covers slow down more quickly in their flight through the air.

1.2 Exercises: 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 scientists do.
2. **Define** the term 'technology'.

Think

3. What type of scientist would investigate rocks to see how old they are?
4. Give an example of the work that a biophysicist and a biochemist might do.
5. Look at the photograph of Australian tennis player, Lleyton Hewitt. **Propose** how each of the following scientists might improve his performance.
   (a) Nutritionist
   (b) Psychologist
   (c) Physicist
6. How might these people use science in their daily work?
   (a) Doctor
   (b) Mechanic
   (c) Farmer
   (d) Firefighter
   (e) Architect

Investigate

7. Read the main section of a daily newspaper, either online or offline. Find an article in which a scientist is referred to or quoted. For this article, **identify**:
   - the scientist's name
   - the discipline or specific field of science they study
   - which organisation they work for
   - what the newspaper article is about and why the scientist has been included in the article.
8. Use the **Da Vinci's machines** weblink in the Resources tab to learn about some of the important machines that Leonardo da Vinci invented.

1.3 The science laboratory

1.3.1 Getting to know the science lab

Scientists often conduct experiments in a laboratory. The science laboratory is different from other classrooms in the school. It is filled with a range of equipment to help you undertake scientific investigations safely.

- Sit quietly for a minute or two and look around the science laboratory.
- List as many differences as you can between the science laboratory and other general classrooms at your school.
- Draw a map of the science laboratory, labelling each of the following items present in your laboratory.
  - Student tables and work benches
  - Teacher's desk or demonstration bench
  - Gas taps
  - Sinks

– Fume cupboard
– Eye wash and safety shower
– Fire extinguisher
– Fire blanket
– Broken glass bin
– Rubbish bin
– Doors

1.3.2 Laboratory equipment

Some of the equipment that you are likely to use in science is listed below. Use the illustrations on the following page to find each item in the laboratory.

Equipment	Use
Beaker	Container for mixing or heating liquids and other substances
Bosshead	Holds the clamp to a retort stand
Bunsen burner	Heats substances
Clamp	Holds objects at the required height on a retort stand
Conical flask	Container for mixing substances or collecting filtered substances
Evaporating dish	Container for heating small amounts of substances over a Bunsen burner
Filter funnel	Used with filter paper to filter substances
Gauze mat	Supports a container over a Bunsen burner while it is heated
Heatproof mat	Protects benches from damage
Measuring cylinder	Used to measure the volume of a liquid accurately
Retort stand	Used with a clamp and bosshead to hold equipment at the required height
Safety glasses	Protect eyes
Spatula	Used to pick up small amounts of solid substances
Stirring rod	Used to stir mixtures
Test tube	Container for holding, heating or mixing small amounts of substances
Test-tube holder	Holds a test tube while it is being heated
Test-tube rack	Holds test tubes upright
Thermometer	Measures temperature
Tongs	Used to hold small objects while they are heated or to pick up hot glassware
Tripod	Supports a gauze mat over a Bunsen burner
Watchglass	Holds small quantities of solids

Some equipment that you are likely to use in the science laboratory



1.3.3 Investigating safely

Doing experiments in science can be exciting, but accidents can happen if investigations are not carried out carefully. There are certain rules that must be followed for your own safety and the safety of others.

Always …

- follow the teacher's instructions
- wear safety glasses and a laboratory coat or apron, and tie back long hair when mixing or heating substances
- point test tubes away from your eyes and away from your fellow students
- push in chairs and keep walkways clear
- inform your teacher if you break equipment, spill chemicals or cut or burn yourself
- wait until hot equipment has cooled before putting it away
- clean your workspace — don't leave any equipment on the bench
- dispose of waste as instructed by your teacher
- wash your hands thoroughly after handling any substances in the laboratory.



Never …

- enter the laboratory without your teacher's permission
- run or push in the laboratory
- eat or drink in the laboratory
- smell or taste chemicals unless your teacher says it's ok. When you do need to smell substances, fan the odour to your nose with your hand
- leave an experiment unattended
- conduct your own experiments without the teacher's approval
- put solid materials down the sink
- pour hazardous chemicals down the sink (check with your teacher)
- put hot objects or broken glass in the bin



Handy hints

- Use a **filter funnel** when pouring from a bottle or container without a lip.
- Never put wooden test-tube holders near a flame.
- Always turn the tap on before putting a **beaker**, **test tube** or **measuring cylinder** under the stream of water.
- Remember that most objects get very hot when exposed to heat or a naked flame.
- Do not use tongs to lift or move beakers.

1.3.4 Working with dangerous chemicals

Your teacher will tell you how to handle the chemicals in each experiment. At times, you may come across warning labels on the substances you are using.

- Always wear gloves and **safety glasses** when using chemicals with this symbol. Corrosive substances can cause severe damage to skin and eyes. Acids are examples of **corrosive** substances.
- These substances are easily set on fire so keep them away from flames. Methylated spirits is **flammable**.
- Chemicals with this label can cause death or serious injury if swallowed or breathed in. They are also dangerous when touched without gloves because they can be absorbed by the skin. Mercury is a **toxic** substance.







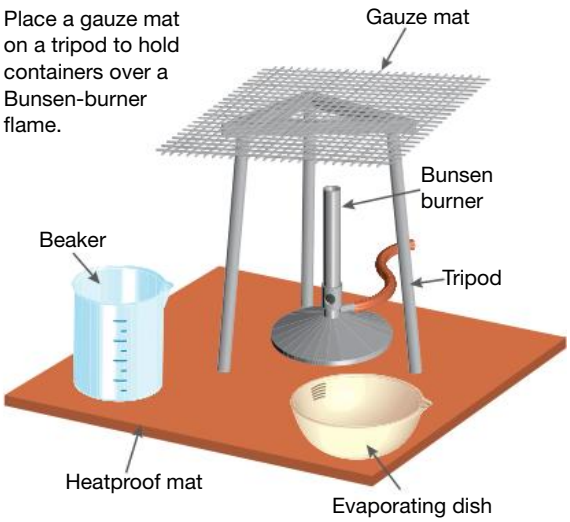
1.3.5 Heating substances

Many experiments that you will conduct in the laboratory require heating. In school laboratories, heating is usually done with a **Bunsen burner**. A Bunsen-burner flame provides heat when a mixture of air and gas is lit.

Always tie hair back, and wear safety glasses and a laboratory coat or apron when using a Bunsen burner.

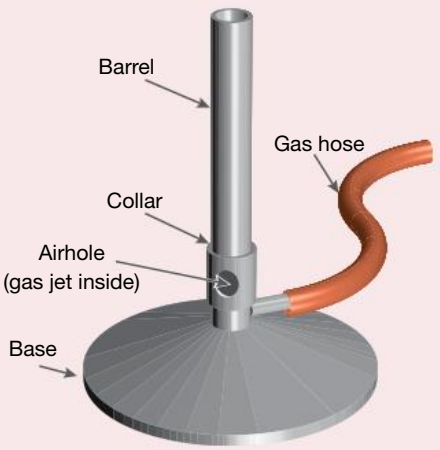
Heating containers

Beakers and evaporating dishes can be placed straight onto a gauze mat for heating. Never look directly into a container while it is being heated. Wait until the equipment has cooled properly before handling it.



A guide to using the Bunsen burner

1. Place the Bunsen burner on a **heatproof mat**.
2. Check that the gas tap is in the 'off' position.
3. Connect the rubber hose to the gas tap.
4. Close the airhole of the Bunsen-burner collar.
5. Light a match and hold it a few centimetres above the barrel.
6. Turn on the gas tap and a yellow flame will appear.
7. Adjust the flame by moving the collar until the airhole is open and a blue flame appears.
8. When the Bunsen burner is not in use, close the collar to return to the yellow safety flame.



INVESTIGATION 1.2

The Bunsen-burner flame

AIM: To determine which Bunsen-burner flame is hotter

You will need:

Bunsen burner
heatproof mat
matches

tongs
pieces of porcelain
safety glasses
clock or watch

- Light the Bunsen burner according to the guide above.
- Open the airhole.
- Using the tongs, hold a piece of porcelain over the flame with the airhole open.
- Record how long it takes for the porcelain to turn red-hot.
- Let the porcelain cool on the heatproof mat.
- Close the airhole.
- Hold the porcelain in the yellow flame for a few minutes until it becomes red hot.

Discussion

1. Describe the flame when the airhole is open. What colour is it? Does it make a noise?
2. Describe the flame when the airhole is closed. Is it easy to see?
3. Does the porcelain turn red-hot in the yellow flame when the airhole is closed?
4. Do you notice anything else about the porcelain after heating in the yellow flame?
5. Which is the hotter flame? What observations did you make that support your answer?

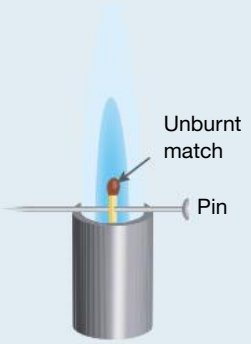
INVESTIGATION 1.3

The hottest part of the flame

AIM: To determine the hottest part of a blue flame

You will need:

Bunsen burner
heatproof mat
matches
safety glasses
nichrome wire
tongs
pin

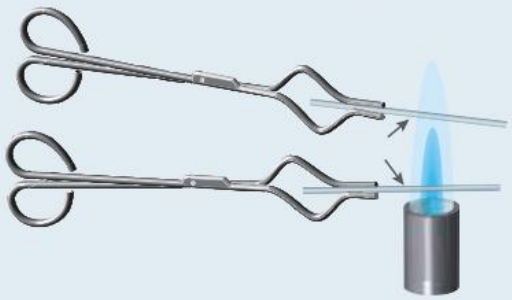


Part A

- Use a pin to hang an unburnt match over the barrel of a Bunsen burner.
- Light the Bunsen burner according to the guide above.
- Turn the collar to produce a blue flame.
- Turn the Bunsen burner off and remove the match and pin with tongs.

Part B

- Re-light the Bunsen burner and turn the collar to produce a blue flame again.
- Use the tongs to hold the wire across the flame, close to the barrel of the Bunsen burner and observe the wire.
- Move the wire up a little and continue observing.



Discussion

1. What happens to the match hanging over the barrel? Explain why.
2. What colour does the wire become when held across the flame?
3. Is the colour of the wire different when it is held at the top of the flame?
4. Draw a diagram of the Bunsen-burner flame, labelling the parts that are hottest.
5. Students often heat substances in a test tube with a Bunsen burner. Why would it be unwise to:
   (a) use a yellow flame rather than a blue flame
   (b) position the test tube at the base of a blue flame?
6. Why is the yellow flame often called the safety flame?

INVESTIGATION 1.4

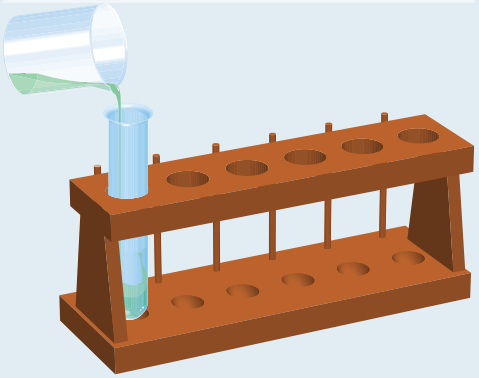
Heating a substance in a test tube

AIM: To practise heating a liquid in a test tube safely

You will need:

100 mL beaker
Bunsen burner and heatproof mat
matches
safety glasses
test tube
test-tube rack
test-tube holder
food colouring

Pouring liquid into a test tube



CAUTION: Before you start heating, check the following:

- **If you have long hair, is it tied back?**
- **Are you wearing safety glasses?**
- **Is the Bunsen burner on a heatproof mat?**



- Carefully pour water from a beaker into a test tube to a depth of about 2 cm as shown in the diagram at above right. Add a drop of food colouring to make it easier to see.
- Light the Bunsen burner correctly and heat the test tube gently in the blue flame as shown below. Remember that the open end of the test tube should be pointing away from you and your fellow students. The base of the test tube should be moved gently in and out of the flame. This prevents the liquid from splashing out of the test tube.
- Make sure that the test tube points away from you and other students.
- Move the base of the test tube in and out of the flame.
- Keep the test-tube holder away from the flame.
- Once the liquid has started boiling, stop heating and turn off the gas to the Bunsen burner. Place the test tube in the test-tube rack. Leave it there until it has cooled before emptying it and cleaning up.

Discussion

1. Why should the test-tube holder be positioned at the top of the test tube?
2. Why is the blue flame used for heating?
3. Make a list of any changes you observed inside the test tube as you heated the water.

1.3 Exercises: 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 purpose of each of the following pieces of equipment.
   (a) Heatproof mat
   (b) Evaporating dish
   (c) Test-tube rack
   (d) Retort stand
2. Give three examples of equipment used when heating objects.
3. **Explain** why you should always wear gloves when working with corrosive substances.
4. If the teacher says it is safe to smell a chemical, **outline** the technique you should use.
5. **Identify** which Bunsen-burner flame is hotter. How do you obtain this coloured flame?

Think

6. **Identify** which item of equipment you would use to:
   (a) hold a test tube that is to be heated
   (b) measure a volume of water exactly
   (c) transfer a small sample of a powder to a beaker
   (d) mix a sample of powder with water so it dissolves.
7. Look carefully at the picture of students in a laboratory below.
   (a) **Identify** at least five dangerous situations you can see.
   (b) **Explain** why each situation is dangerous.
8. The following statements are all incorrect. Rewrite them so that they are correct.
   (a) Matches can be safely washed down the sink.
   (b) Always point a test tube towards you when heating so you can see what is happening inside it.
   (c) Safety glasses need to be worn only when heating over a blue Bunsen-burner flame.
   (d) Water spills do not need to be cleaned up because they are not dangerous.

Create

9. Select one of the safety rules and choose a strategy for publicising your message to the class. You might create a safety poster, video clip or play.
10. Use the **Robert Bunsen** weblink to learn about the man after whom the Bunsen burner was named.

Danger in the laboratory



learnON RESOURCES — ONLINE ONLY

Try out this interactivity: Using equipment (int-0200)

Explore more with this weblink: Robert Bunsen

Complete this digital doc: Worksheet 1.1: Safety in the laboratory (doc-12345)

Complete this digital doc: Worksheet 1.2: Safety rules (doc-12346)

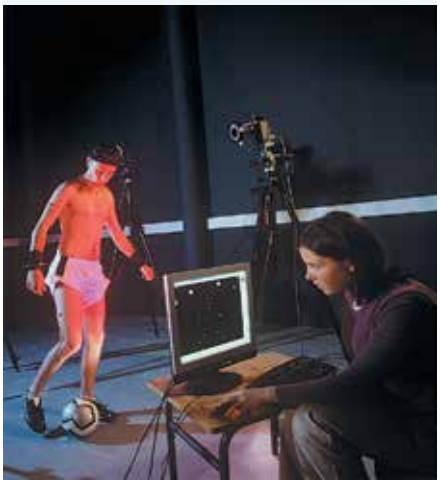
1.4 Observing and inferring

As scientists conduct their experiments, it is important to keep a record of all the measurements and observations made. Some observations are **qualitative**, meaning that they describe in words the results of an investigation: for example, 'The red kangaroo sheltered under a tree during the hottest part of the day'. **Quantitative** observations involve a numerical measurement: for example, 'The male red kangaroo had a mass of 85.3 kg'.

1.4.1 Measuring

Experiments conducted in science often involve measuring quantities such as length and mass. Measuring gives us an accurate way of knowing whether quantities change and, if so, by how much. This helps scientists to make conclusions from their experiments and to develop new ideas. Scientists all around the world use the metric system of units for their measurements.

A professional sportsman has his kicking action carefully measured and analysed by a **biomechanist**. Note the markers attached to his body that are being imaged on the computer.



1.4.2 Measuring length

Scientists measure the lengths of different objects accurately to compare sizes and estimate growth. The biologists in the photograph below are measuring the mass and condition of a tranquillised polar bear as part of a study aimed at conserving these animals in their Arctic home.

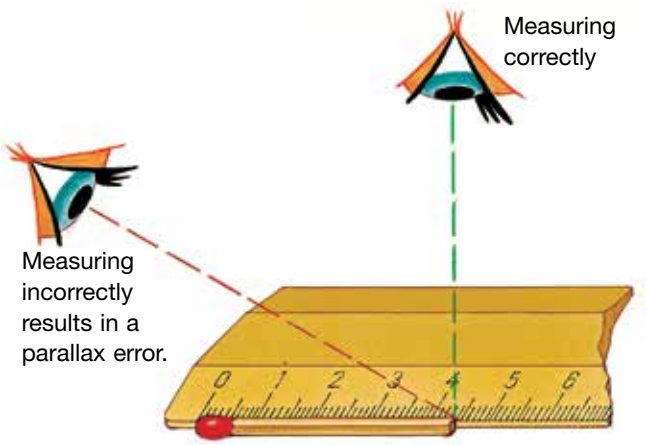
The standard unit for length is the metre (m). But length can also be measured in millimetres (mm), centimetres (cm) or kilometres (km). The table at right shows how to convert between some common units of measurement.



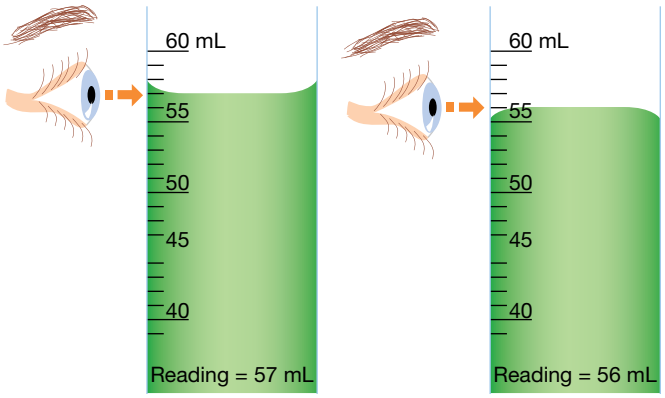
Converting measurements
Length 1 kilometre (km) = 1000 metres (m) 1 metre (m) = 100 centimetres (cm) 1 centimetre (cm) = 10 millimetres (mm)
Volume 1 litre (L) = 1000 millilitres (mL) 1 millilitre (mL) = 1 cubic centimetre (cm^3)
Mass 1 kilogram (kg) = 1000 grams (g)
Time 1 hour (h) = 60 minutes (min) 1 minute (min) = 60 seconds (s)

1.4.3 Parallax error

Measurements should always be made with your eye in line with the reading you are taking. When scales are read from a different angle, the reading is not accurate. This type of reading error is called **parallax error**.



1.4.4 Measuring volume



Liquids in containers such as measuring cylinders are often curved at the top edge. The curve is called a **meniscus**. The edges of the meniscus may curve up or down. We always measure the volume of liquids from the middle flat section of the meniscus.

1.4.5 Measuring temperature

A **thermometer** is used to measure temperature. The unit of measurement commonly used is degrees Celsius (°C). The thermometers used in schools are filled with alcohol, dyed red so that they are easier to read. When using thermometers, remember these points.



- Never rest the bulb of the thermometer on the bottom of a container being heated as the bottom may be hotter than the rest of its contents.
- Ensure that the liquid for which you are measuring the temperature fully covers the thermometer bulb.
- Never use the thermometer as a stirring rod.
- Read the thermometer with your eye level with the top of the alcohol column.
- Do not rest a thermometer near the edge of a bench where it is likely to fall off.

1.4.6 Using data loggers

A data logger is an electronic device that collects and records scientific measurements, which we call **data**. The measurement recorded by a data logger depends on the **sensor** that is connected to it. The sensor does the measuring and sends the information to the data logger. There are a number of different sensors available; for example, if a temperature sensor is attached to the data logger, temperature is measured and recorded.

Data loggers are useful devices because they generally measure quantities very accurately. For example, they may record temperature accurate to 0.1 °C. Some data loggers can also store thousands of individual measurements and allow them to be downloaded to a computer to be converted to tables and graphs.

A data logger and temperature sensors

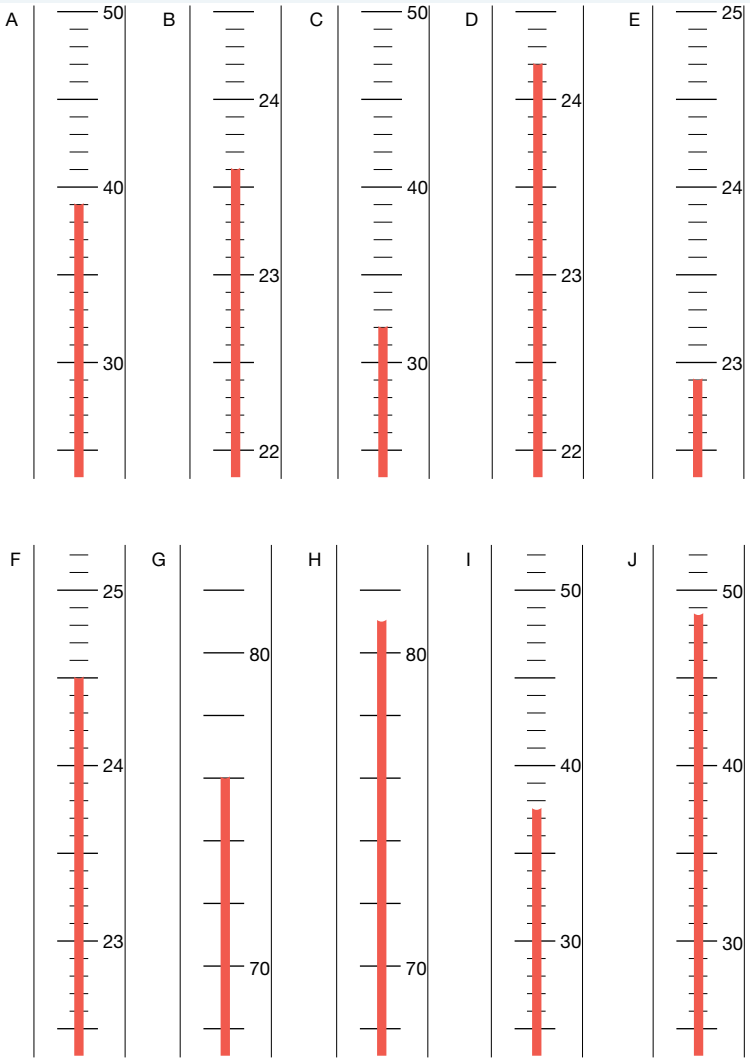


1.4.7 Reading scales

In science, a scale or set of numbered markings generally accompanies each measuring device. For example, your ruler measures length, and its scale has markings enabling you to measure with an accuracy of 0.1 cm. A laboratory thermometer has a scale that measures temperature with an accuracy of 0.5 °C.

When reading a scale, it is important to determine what each of the markings on the scale represents. Practise reading the scales on next the page.

The temperatures measured by thermometers A and B are 39 °C and 23.6 °C, respectively. What are the temperatures measured by thermometers C to J?



INVESTIGATION 1.5

Measuring temperature

AIM: To measure and record temperature

You will need:

laboratory thermometer or data logger and temperature sensor
250 mL beaker
paper towel
ice

- Use the thermometer or data logger to measure the temperature of:
  (a) the air inside the school laboratory
  (b) the air outside the school laboratory
  (c) icy water in a small beaker
  (d) cold tap water in a small beaker
  (e) warm tap water in a small beaker
  (f) your armpit (take care, the thermometer is a delicate instrument).

CAUTION: Do not put the thermometer in your mouth!

- Copy and complete the following table so that you can record your measurements neatly.

Measuring temperature

Substance or location	Temperature (°C)
Air inside the school laboratory	
Air outside the school laboratory	
Icy water in a small beaker	
Tap water in a small beaker	
Warm tap water in a small beaker	
My armpit	

Discussion

1. Which substance or location was the coldest?
2. Which substance or location was the hottest?
3. What is the accuracy of your thermometer or data logger and sensor?

HOW ABOUT THAT!

Hot and cold

The highest air temperature ever measured on Earth is 58 °C. The measurement was taken in 1922 in Libya. The lowest temperature ever measured was in 1983 in Antarctica. That temperature was –86.6 °C.



1.4.8 Measuring mass

Mass is usually measured in kilograms (kg); however, in the science laboratory, you will often measure smaller masses and so use the smaller unit, grams (g). You will use either a **beam balance** or **electronic scales** to measure mass accurately.

Electronic scales are the easiest to use. Simply adjust the balance reading to zero by pressing the 'tare' button, place the object to be measured on the scales, and read the mass from the digital display.

Follow these steps to measure mass using a beam balance:

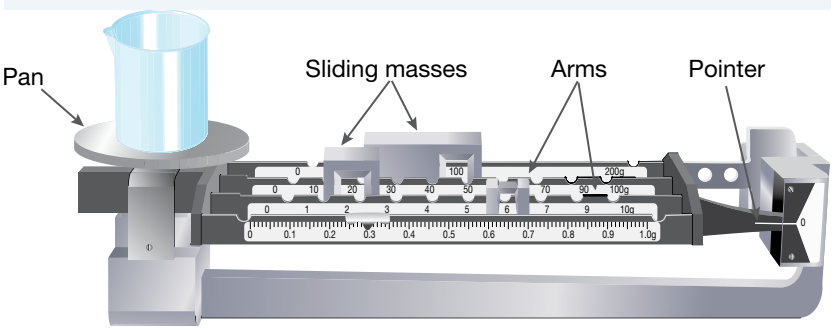
Step 1: Make sure that the balance is 'zeroed' before using it by moving all of the sliding masses to the zero notches and checking that the pointer on the arm of the balance lines up with zero.

Step 2: Put the object to be measured on the pan of the beam balance.

Chemical substances should not be placed directly on the pan. To find the mass of these **substances**, they need to be poured into a container. The dry, empty container should be measured first, and its mass should be subtracted from the mass of the container with the substance in it.

Step 3: When an object is put on the pan, the pointer moves.

A beam balance



You can determine the object's mass by 'zeroing' the pointer. Do this by moving the heaviest sliding mass towards the pointer. Slide it until it just overbalances the pointer, and then slide it back to the nearest notch. Repeat this with the smaller masses in turn, except the smallest sliding mass. The smallest mass should balance the pointer, so that it lines up with the zero (balance) mark.

Step 4: Add the masses on each of the arms to determine the total mass. The beaker in the diagram below has a mass of 126.3 grams.

INVESTIGATION 1.6

Estimating mass

AIM: To accurately measure and record the masses of some common objects

You will need:

beam balance or electronic scales
pen
safety glasses
watchglass
teaspoon
watch
100 mL beaker
50 mL water
sugar

- Record your estimates of the masses of each of the items in a table like the one below.

Estimating and measuring mass

Item	Estimated mass (g)	Measured mass (g)	Difference (g)	Percentage error (%)
Pen				
Watch				
Safety glasses				
50 mL water				
2 teaspoons of sugar				

- Measure the masses of the pen, watch and safety glasses using a beam balance or electronic scales.
- The water and the sugar cannot be put directly on the pan. Record the masses of the beaker and the watchglass on their own.
- Add 50 mL of water to the beaker. Record the combined mass of the water and the beaker. Subtract the mass of the beaker alone from the combined mass. Do the same with 2 teaspoons of sugar in the watchglass. Alternatively, put the empty container on the electronic scales before adding the water or sugar, and press 'tare'.
- Record in the table whether your estimated mass was higher or lower than the measured mass, and by how many grams. This is called the difference.
- Determine the degree to which your estimates were incorrect by calculating them as a percentage error. For each item, calculate the percentage error using:

$$\frac{\text{difference (g)}}{\text{measured mass (g)}} \times 100 = \text{percentage error}$$

Discussion

1. Which was your most accurate estimation?
2. By what percentage did your least accurate estimation vary from the measured mass?
3. Is it easier to estimate larger or smaller masses? Explain why you think this is the case.

1.4.9 Measuring time

We use clocks and watches to tell the time, but scientists often need to record how long an event takes. To do this accurately, they use stopwatches or electronic counters. The standard unit for measuring time is the second(s).

Familiarise yourself with a stopwatch. There is generally a start/stop button and a reset button. Push the reset button when you wish to start timing in a new experiment and when you have finished timing your experiment and need to return your stopwatch to zero.

A typical stopwatch used to record time accurately



INVESTIGATION 1.7

Timing a fall

AIM: To practise timing an event

You will need:

stopwatch
pen

- Time how long it takes for a pen to fall from the top of the bench to the ground. Repeat two more times.
- Calculate the average time taken for the three trials.
- Repeat your experiment but swap roles within your group so that each member has a turn timing, recording and managing (such as saying 'go' when it's time to start the drop).
- Record your results in a table like that below.

Name of student timing	Time taken (s)			
	1	2	3	Average

Discussion

1. Was the time taken to fall the same in each trial? Can you explain why?
2. Explain why it is useful to calculate an average.
3. Explain why you used a stopwatch in this experiment instead of the second hand of a clock or watch.

Making observations

Some of the most important scientific discoveries have come about through simple scientific observations. For example, in 1928, Alexander Fleming accidentally discovered the first antibiotic when he was observing mould (read more about this in Alexander Fleming).

INVESTIGATION 1.8

How observant are you?

AIM: To observe the changes that occur in a burning candle

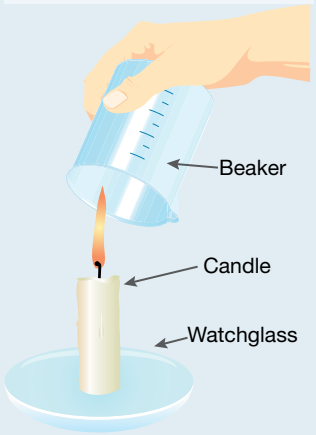
You will need:

large beaker
short candle

lid or watchglass
matches
electronic scales

- First, weigh the candle and lid (or watchglass) using electronic scales and record your results.
- Light the candle.
- Observe the candle for several minutes and record as many observations as you can while it is alight. (Interestingly, Michael Faraday, a nineteenth century scientist famous for his discoveries in electricity and chemistry, was able to make 53 observations of a burning candle!)
- After several minutes, place an upturned beaker over the candle and continue to record your observations.
- Weigh the candle and lid (or watchglass) again and record your results.

Place a beaker over the candle after burning for several minutes.



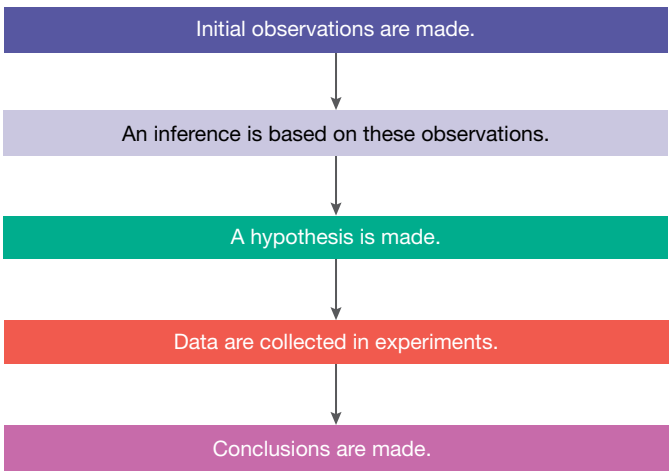
Discussion

1. How many observations did you record? What was the greatest number recorded by a member of your class?
2. What change occurred in the mass of the candle and lid?
3. Can you suggest why the mass of the candle may have changed?

1.4.10 Inferring and hypothesising

After making some initial observations, scientists may make an **inference** or suggested explanation about what has happened. For example, you may have inferred in *Investigation 1.8* that the wax of the candle was burnt in the experiment, causing the candle to lose mass.

Scientists wishing to investigate further often come up with a **hypothesis** or suggestion describing what may happen. Hypotheses should be measurable so that they can be tested. For example, in *Investigation 1.8*, you might hypothesise that the mass lost by the candle goes into producing the mass of smoke observed. You might conduct further experiments to produce quantitative observations (or data) that support or reject your hypothesis. If the observations support your hypothesis, you might be able to make the **conclusion** that the mass lost by the candle was converted to smoke. You might like to re-design *Investigation 1.8* to test this hypothesis.



A summary of the process of investigating is shown above right.

1.4 Exercises: 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.

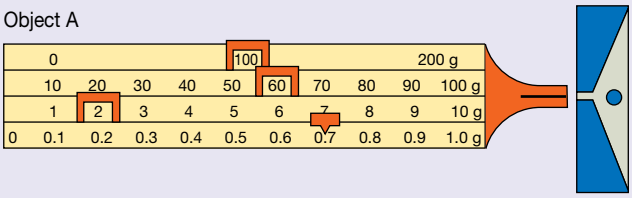
Remember

1. **Describe** what you must be sure to do when measuring the volume of a liquid accurately.
2. **Explain** why you should not rest the bulb of a thermometer on the bottom of the container when measuring the temperature of a liquid while heating.
3. **Identify** the standard unit of mass.
4. **Identify** a device used to measure the mass of an object in a school laboratory.

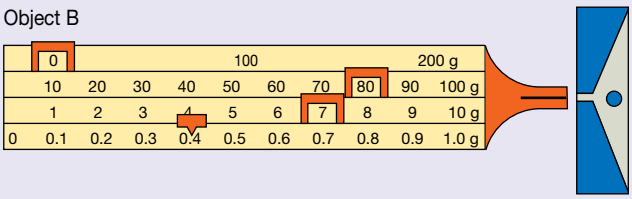
Think

5. Look at the figure on page 15 showing parallax error.
   (a) What is the correct length of the matchstick shown?
   (b) What approximate length of the matchstick would you get due to parallax error?
6. Convert the following lengths into metres.
   (a) 150 centimetres
   (b) 25 centimetres
7. Luke measured the mass of a beaker of water as 240 grams. He tipped out the water and measured the mass of the beaker as 105 grams.
   (a) **Calculate** the mass of the water in grams.
   (b) Express the mass of the water in kilograms.
   (c) **Explain** how Luke could have improved the procedure in his experiment to achieve a more accurate measurement of the mass of the water.
8. Decide whether each of the following statements is an observation, hypothesis or conclusion.
   (a) Candles require oxygen from the air to burn.
   (b) The candle went out when I placed a glass over it.
   (c) Without oxygen from the air, a candle would quickly go out.
9. Look at the following diagrams of measurements obtained from a beam balance.
   (a) What is the mass of object A?
   (b) What is the mass of object B?
   (c) What is the largest mass that could be measured on this beam balance?

Object A



Object B



Investigate

10. Sit quietly in a nearby outdoor location and write down as many observations as you can within five minutes. Use as many senses as you can, except taste.
    (a) **Identify** the sense that you used the most.
    (b) Which other senses did you use?
    (c) **Compare** your observations with those of other classmates. What interesting observations did others make?

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Try out this interactivity: Reading scales (int-0201)

Complete this digital doc: Worksheet 1.3: Observations and inferences (doc-12347)

1.5 Reporting on investigations

1.5.1 Experiment reports

Once scientists have completed an investigation, they need to communicate to other scientists what they did, their qualitative and quantitative observations and their conclusions. This is done using a scientific report. You may have some experience in writing reports in other subjects. However, a scientific report takes the format outlined below.

Aim

This is what you intended to do in the investigation.

Materials

This is a list of all the equipment and chemicals that were used.

Procedure (method)

This is the procedure followed in the investigation, described as a series of steps. It may be useful to include a labelled diagram of the set-up of equipment used. Be sure to include what you are actually recording in the experiment.

Results

This is a presentation of your data, and it may include qualitative observations. Data are usually organised into tables and presented as graphs.

Discussion

In this section, scientists explain their results: why they think they obtained the results they did. They may refer to the research of other scientists. They may also describe any problems encountered in the investigation and make suggestions on improvements.

Conclusion

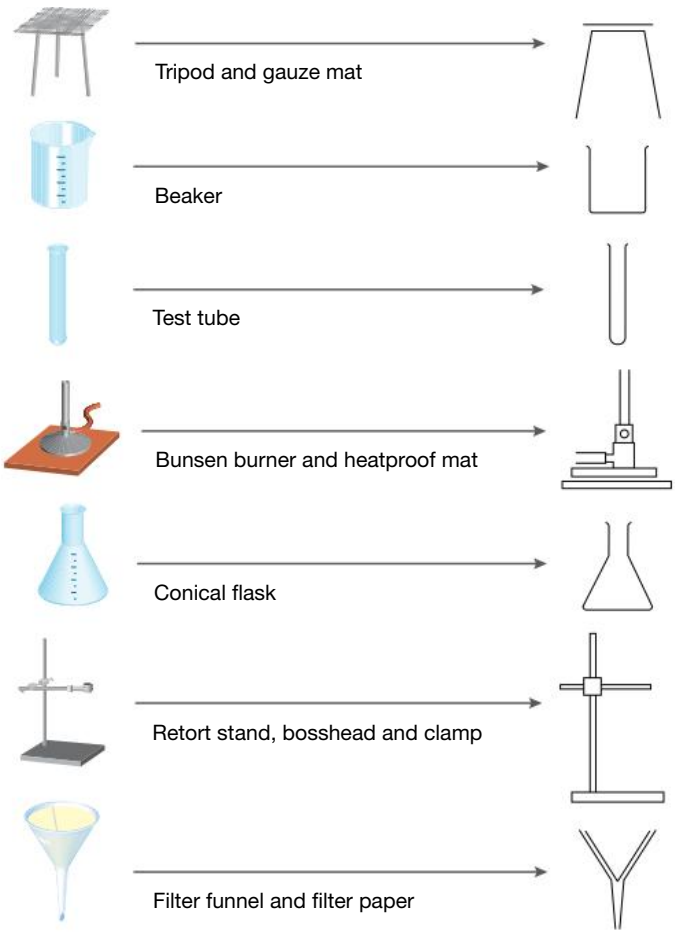
This is a summary of the overall findings. The conclusion must relate to the aim of the investigation.

1.5.2 Drawing laboratory equipment

Scientific drawings can be used in laboratory reports to show how equipment was set up. It is important for the drawings to be clear and easy to understand. When drawing scientific diagrams, you should:

- always draw in pencil
- use a ruler to draw straight lines
- label the equipment drawn
- draw only a cross-section of the equipment
- not draw lines closing the top of open glassware.

Some examples of equipment drawn scientifically are shown below.



1.5.3 Keeping a record

When recording observations, it is helpful to organise the data in a table. Information presented in this way is often easier to read. Graphs can then be constructed from the table to make it even easier to see patterns in the data.

The heading for each column is a clear label of what has been measured.

Always include the units used in the headings.

Enter the data in the body of the table. Do not include units in this part of the table.

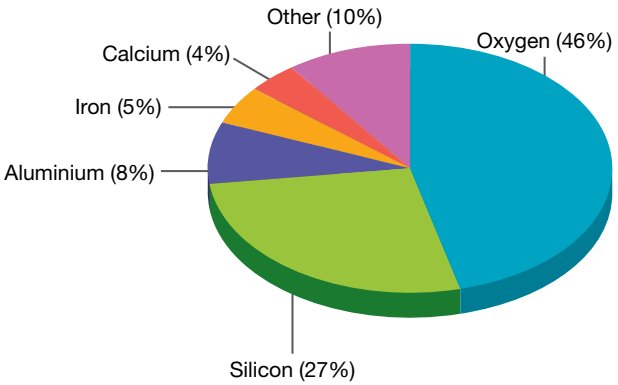
Use a ruler to draw lines for rows, columns and borders.

Distance (cm)	Time for ant to travel between markers (s)
0	0
2	3
4	7
6	8
8	12

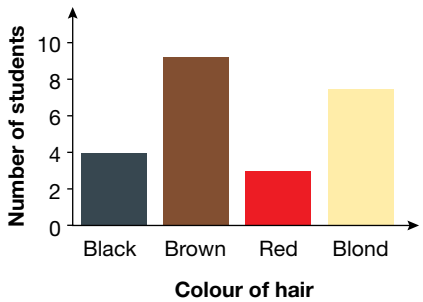
1.5.4 Graphing

Graphs are used to make data easier to interpret. The type of graph used depends on the type of data to be displayed.

Pie charts are useful for showing the parts that make up a whole. For example, a pie chart can be used to show the percentages of different substances in the Earth's crust.



Bar and column graphs are used to display data that can be placed in categories. For example, a bar graph can be used to show the number of students in a class with a particular hair colour.



An example of a good quality report of an experiment

Date: 29 February

Dissolving sugar

Aim:

To find out how much sugar will dissolve in hot water compared with cold water

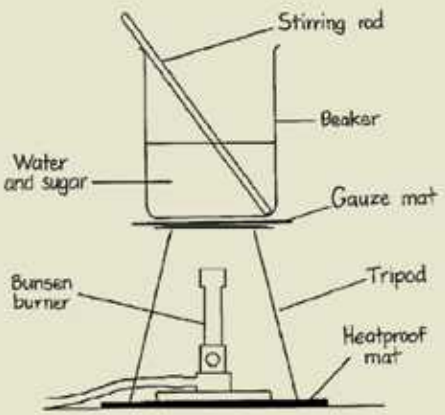
Materials:

Beaker, heatproof mat, Bunsen burner, tripod, gauze mat, matches, spatula, stirring rod, sugar, water

Method:

1. A spatula was used to add sugar to 100 mL of cold water in a beaker. The sugar was stirred and more added until no more would dissolve. The amount of sugar dissolved was recorded.

2. The mixture of sugar and water was heated with a Bunsen burner for 4 minutes and the extra amount of sugar that could be dissolved was recorded.



Results:

Amount of sugar dissolved in cold water = 2 spatulas
Extra amount of sugar dissolved in hot water = 4 spatulas
Total amount of sugar dissolved in hot water = 6 spatulas

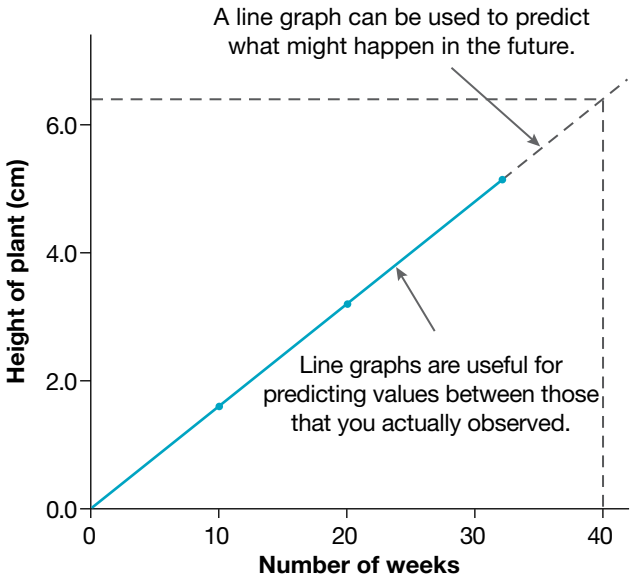
Discussion:

I was able to dissolve more sugar in the hot water than in the cold water. A thermometer could have been used to measure the temperature of the water. The amount of sugar could have been measured more accurately by adding smaller amounts at a time.

Conclusion:

Three times as much sugar dissolves in hot water as in cold water.

Line graphs are often used to represent continuous or connected data. A line graph is used to show how a measurement changes. For example, line graphs could be used to show how quickly a plant grows over time.



INVESTIGATION 1.9

Recording observations in a table

AIM: To record observations from experiments

You will need:

test tubes
50 mL beaker
eye-dropper
vinegar
sodium carbonate
methylated spirits
starch suspension
safety glasses
test-tube rack
spatula
drinking straw
sodium bicarbonate
copper sulfate
limewater
iodine solution

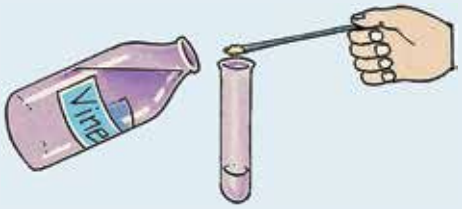
CAUTION: Safety glasses should be worn while conducting these experiments.

- Draw a table like the one below to record your observations in of each of the following activities.

Activity	Summary of what was done	Observations
1		
2		
3		
4		
5		

Activity 1

- Pour vinegar into a clean test tube to a depth of about 1 cm. Add a spatula full of sodium bicarbonate.



Activity 2

- Quarter-fill two clean test tubes with water. Add a dry spatula full of sodium carbonate to one test tube. Shake the tube until the sodium carbonate dissolves. Add a dry spatula full of copper sulfate to the other test tube and shake it until the crystals dissolve. Pour the contents of the second test tube into the first.



Activity 3

- Use an eye-dropper to put one drop of methylated spirits onto the back of your hand. Blow air gently across the back of your hand.



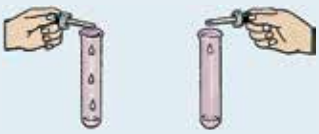
Activity 4

- Quarter-fill a very small beaker with limewater. Gently blow out through a drinking straw into the limewater. Be careful not to share straws.



Activity 5

- Put a few drops of starch suspension in a clean test tube. Add a drop of iodine solution.



CAUTION: Take care not to get iodine solution on your skin or clothes.

Discussion

1. What senses did you use in making your observations?
2. Outline two safety precautions involved in this investigation.
3. Explain why it is important to use small quantities of chemicals when doing experiments like these.
4. Explain why it is useful to present the observations in a table.
5. In activity 4, you had to pour limewater into the beaker. If you took more limewater than required, explain why it is not a good idea to return any unused limewater to the original bottle.

INVESTIGATION 1.10

Graphing temperature

AIM: To observe how the temperature of water changes while it is heated over a Bunsen burner

A line graph is a useful way to present the results of an experiment and helps to demonstrate any trends or patterns in the results. A line graph can also be used to predict values that occur between, or outside, those measured during an experiment.

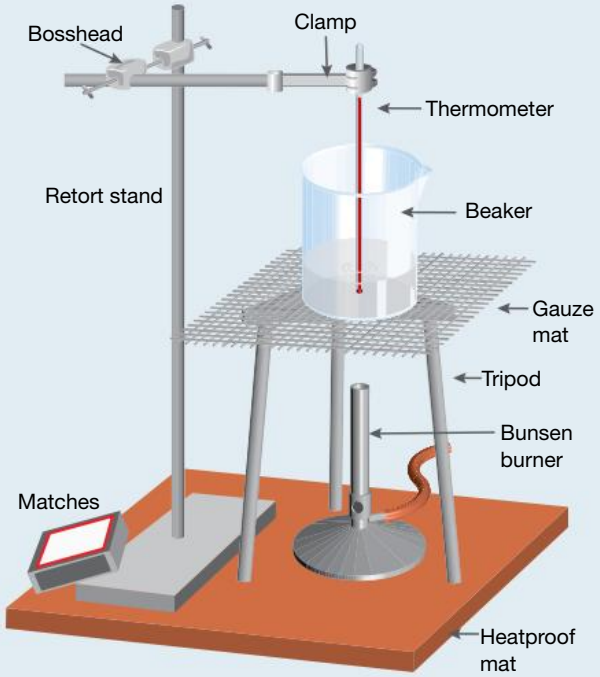
You will need:

100 mL measuring cylinder
250 mL beaker
Bunsen burner
heatproof mat
matches
tripod
gauze mat
retort stand, bosshead and clamp
thermometer or data logger and temperature sensor
stopwatch
safety glasses

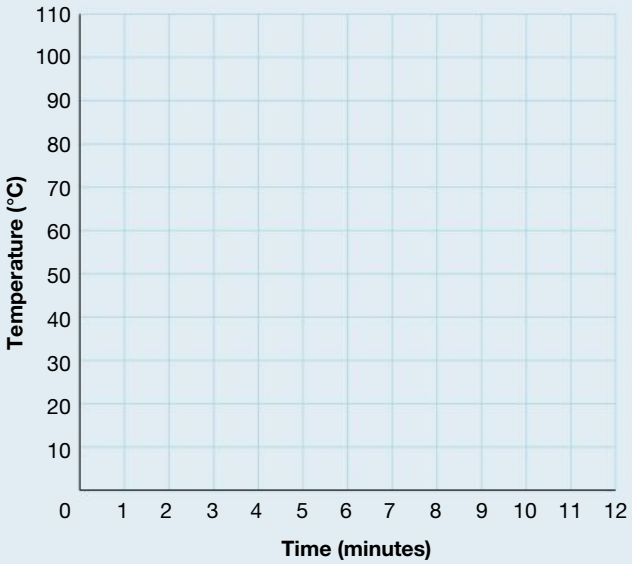
- Use a measuring cylinder to measure 100 mL of water.
- Pour the water into the beaker.
- Set up the equipment as shown in the diagram. Make sure that the bulb of the thermometer is not on the bottom of the beaker or out of the water.
- Wait for a minute to allow the thermometer to adjust to the water temperature.
- Measure the initial temperature of the water and record it in a table. The initial temperature is recorded when time is 0 minutes.

Time (min)	Temp. (°C)	Time (min)	Temp. (°C)
0		6	
1		7	
2		8	
3		9	
4		10	
5			

- Put your safety glasses on.
- Light the Bunsen burner according to the guide on page 11.
- Open the airhole and heat the beaker over a blue flame.
- Measure and record the temperature of the water every minute for 10 minutes.
- Turn off the Bunsen burner and allow the equipment to cool.



- Plot the data you have collected on a sheet of graph paper using labels like those below.



- Complete the line graph by drawing a smooth line near as many points as possible to show the overall trend in the water temperature over time.

Discussion

1. Why didn't you record the starting temperature of the water as soon as you poured the water into the beaker?
2. Describe in words how the temperature increases.
3. How does your graph compare with those of other groups?
4. Predict what would happen to the temperature of the water if you continued heating for another two minutes.

1.5 Exercises: 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 scientists write reports about the experiments they conduct.
2. **Identify** the part of a laboratory report where a graph of temperature vs time would be drawn.
3. **Distinguish** between the results of an experiment and the conclusions made.
4. **Identify** the headings of your report of an experiment under which the following information should be included.
   (a) Suggestions for improvements to your experiment
   (b) Data collected
   (c) A description of what you did
   (d) A statement saying what you discovered by doing the experiment
5. A hypothesis is often included in a scientific report, usually after the 'aim' heading. **Define** the term 'hypothesis'.

Think

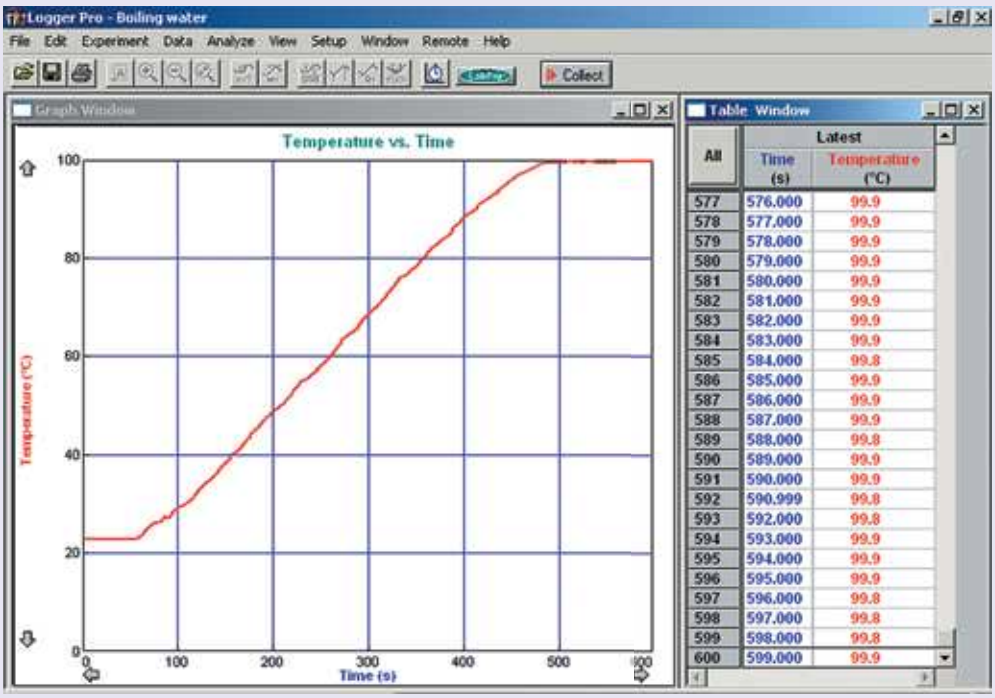
6. A student measured the temperature in each of the classrooms at her school so she could compare them. **Identify** the type of graph that the student should select to display her results.
7. **Construct** a neat, labelled, scientific diagram of the two sets of equipment that would be needed to perform the following activity safely.
   - Part 1: Muddy salt water is being poured from a beaker into a filter funnel (with filter paper). The filter funnel is resting in the opening of a conical flask.
   - Part 2: The filtered salt water, now in an evaporating dish, is being heated by a Bunsen burner. The evaporating dish is being supported by a gauze mat on a tripod.

Investigate

8. **Investigate** whether adding salt to water changes the temperature at which water boils. Design an experiment to test your answer. Write a scientific report outlining the design of your investigation.

Analyse And Evaluate

9. The computer screen below shows data collected by a data logger for the experiment in which water is heated to boiling point in a beaker.



A temperature sensor was used to take the measurements.

If you were at this computer, you could scroll through every temperature measurement in the table. The computer has graphed all these data. Now let's see how much you've learned about interpreting line graphs.

(a) How often did the data logger collect temperature readings?
(b) How long did the whole experiment go for?
(c) **Identify** the number of individual temperature readings the data logger has stored.
(d) **Identify** when the heating of the water began.
(e) **Identify** the temperature of the water when heating began.
(f) **Identify** the temperature of the water when heating finished.
(g) **Identify** when the water began to boil.
(h) **Calculate** the rate (in degrees per second) that the water temperature rose between 100 and 400 seconds.
(i) The water continued to be heated even when its temperature reached boiling point, yet its temperature did not rise beyond 100 °C. What has happened to all the energy that was being put into the water if it isn't causing the water temperature to rise? (*Hint:* Think about what happens to water while it is boiling.)

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Complete this digital doc: Worksheet 1.4: Scientific reports (doc-12348)
Complete this digital doc: Worksheet 1.5: Scientific drawing skills (doc-12349)
Complete this digital doc: Worksheet 1.6: Data analysis (doc-12350)

1.6 Designing investigations

1.6.1 Fair tests

When carrying out investigations, it is important to do so scientifically. This means, for example, using the most accurate equipment available. In many of the experiments you will do, the procedure you need to follow will be provided for you. In some cases though, you will need to design your own experiments as part of your investigation. Let's look at some important principles to consider when designing investigations.

Experiments are generally designed to test hypotheses. A hypothesis is a testable idea developed from previous observations. For example, David loved playing handball in the playground, and it seemed to him that tennis balls falling from greater heights bounced higher. He wanted to test his hypothesis.

An important part of any investigation is to consider all the factors, or **variables**, that may affect the outcome of an experiment. David thought that the most important variable to affect the bounce of a ball was the height it fell from.

In most cases, many factors may affect the outcome of an experiment. For example, the height that a ball bounces might depend not only on the height from which it fell but also on the type of ball; after all, would you expect a cricket ball to bounce as much as a tennis ball? The amount of air in a ball might also affect its bounce; a fully inflated basketball usually bounces higher than a partially deflated one.

When designing investigations in science, it is important to design a **fair test**. In a fair test, only one variable is changed at a time, and all other variables are **controlled**, or kept the same. If this wasn't the case, it would be impossible to tell which variable caused the result we are studying.

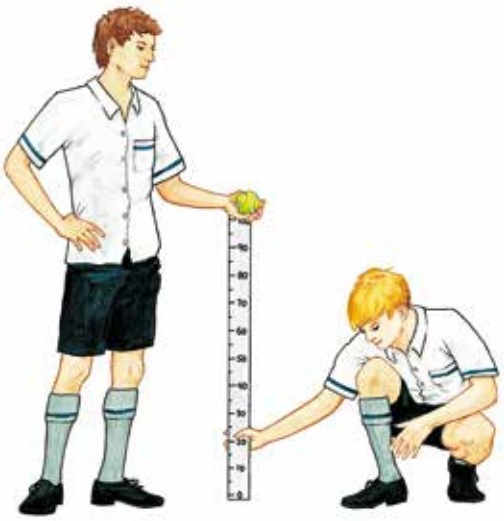
The phrase ‘Cows Moo Softly’ is useful in remembering how to plan a fair test:

- Change one thing.
- Measure something.
- Keep everything else the same.

In David’s case, he will vary the height from which a tennis ball is dropped but will keep everything else the same, such as the type of ball, how much air is in the ball and the type of surface onto which it is dropped. To enable him to make conclusions from his investigation, he collected quantitative data; that is, he measured the height of the tennis ball’s bounce and repeated his experiment several times for each height tested.

When designing fair tests, you might find it helpful to use a table like the one below to identify all the variables.

Investigating whether the height from which a ball is dropped affects the height of the bounce



Investigation: Does the height from which a ball is dropped affect the height of its bounce?

Independent variable (What I will change)	Dependent variable (What I will measure)	Controlled variables (What I will keep the same)
• The height from which the ball is dropped	• The height of the ball’s bounce	• The type of ball • How much air is in the ball • The type of surface onto which it is dropped • Dropping the ball from a stationary point

Including a control

In some investigations, it is important to include a **control**. A control is a **trial** of the experiment in which the independent variable being tested is not applied. Results from the control are compared with those obtained when the independent variable has been included. This allows us to test whether the independent variable we are investigating really has an effect, or whether other variables that we may not have thought of could be playing a part.

For example, if we want to investigate whether a ball being wet affects how high it bounces, we might compare the height of a wet ball’s bounce with that of a dry ball dropped from the same height. The results obtained using the dry ball act as a control, or comparison.

1.6.2 Reliability

The results obtained from experiments are used to make conclusions, but what if the measurements made are incorrect? Errors often arise in experiments; sometimes they are one-off errors, perhaps because the experiment was not done carefully. Other times the errors may be more difficult to eradicate because the equipment we used is not as accurate as it should be, or the samples we are testing are faulty.

Trial	Height of bounce (cm)	
	Dry tennis ball (control)	Wet tennis ball
1	70	70
2	65	62
3	68	60
4	69	63
5	72	65
Average	69	64

To prevent one-off errors from affecting your conclusions, experiments should be repeated a number of times. When repeating experiments, they should be done in exactly the same way each time. For example, when

comparing the bounce of a wet ball with that of a dry ball, it would be sensible to repeat the experiment, say, five times with the same ball and with the same controlled variables. If the results obtained are similar each time, then we say the results are **reliable**. If there was a significant difference between your results for each test, you may need to review the way in which the experiment was done. Would you say the results presented in the table at bottom of the opposite page are reliable?

What conclusion would you make based on the average results? Would you have drawn the same conclusion based on the results of trial 1 only?

Including a control (left) to test whether wetting a ball (right) affects how high it bounces



INVESTIGATION 1.11

Floating in salty water

AIM: To investigate whether the salinity of water affects how high an object floats in water

The water in the Dead Sea, a lake near Jordan in the Middle East, has an unusually high salinity; in fact, it is nine times more saline than the ocean. Tourists flock to the lake because it is believed the water has health benefits and to experience the water's unusually high buoyancy.

Tourists demonstrate the unusual buoyancy caused by high salinity in the Dead Sea.



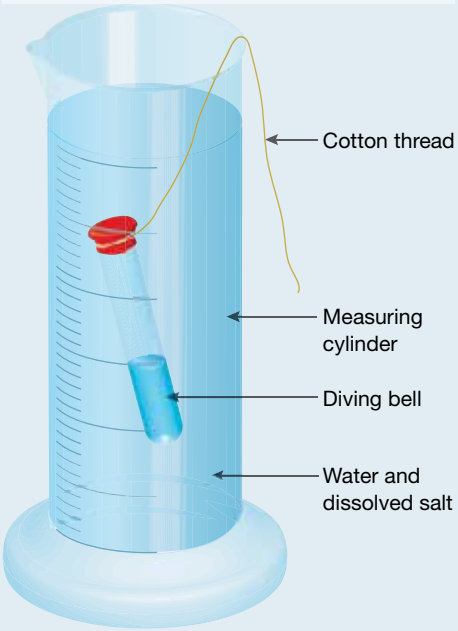
You will need:

100 mL measuring cylinder
small test tube
cork or rubber stopper
cotton thread
permanent marker
scissors
table salt
teaspoon or spatula

- Fill the measuring cylinder to the 100 mL mark with tap water.
- Make a 'diving bell' by half-filling a test tube with tap water; seal the top with a stopper.
- Tie a piece of cotton thread securely around the top of the test tube so it can be carefully moved in and out of the measuring cylinder.

- Check that the test tube floats off the bottom but not higher than halfway up the measuring cylinder. If not, adjust the volume of water in the test tube.
- Put the diving bell in the measuring cylinder and mark the position of the *bottom* of the diving bell on the measuring cylinder's scale. Record this value.
- Carefully remove the diving bell.
- Add a level teaspoon of table salt to the measuring cylinder and dissolve it in the water by shaking carefully or stirring.
- Put the diving bell back in and mark and record its position.
- Repeat this experiment using a second, a third and, finally, a fourth teaspoon of salt.
- Design a suitable table to record your results — you will need a column indicating the number of teaspoons of salt added and a column listing the position of the diving bell (using the scale on the measuring cylinder).
- Draw a line graph of salinity (teaspoons of salt added) on the *x*-axis versus the height of the diving bell (reading on the measuring cylinder) on the *y*-axis, and draw a smooth line of best fit.

The diving bell



Discussion

1. Write a conclusion to the experiment about whether the salinity of water affects how high an object floats in water.
2. Identify the control in this experiment.
3. Explain how these results support your conclusion.
4. Repeating this experiment would be very time consuming so, to check the reliability of your findings, compare your results with those of other groups. The easiest way to do that is to compare others' graphs with yours.
5. Extrapolate (extend) your graph to predict the position of the diving bell if six teaspoons of salt were added.

1.6 Exercises: 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

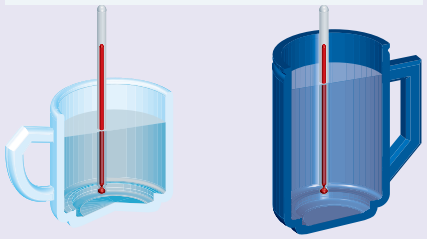
1. **Define** the term 'variable'.
2. **Explain** the difference between the independent and dependent variables in an experiment.
3. **Explain** why only one variable at a time should be changed in experiments.

Think

4. **Identify** some variables that might affect:
   (a) how quickly a pot plant grows
   (b) the cost of an airfare overseas
   (c) the time it takes you to travel to school in the morning.
5. Advertisements for washing powders and liquids often claim that they are more effective than others. Imagine you are conducting an experiment to test the effectiveness of a range of washing powders and liquids.
   (a) Prepare an **outline** of a procedure for your experiment.
   (b) List the variables that you will need to control.
   (c) Which variable will you change?
   (d) How will you **compare** the results of your tests?

6. Catherine and Celine are trying to find out whether ceramic or glass cups are better for keeping water hot. The illustration right side shows their experiment in progress.
   (a) **Identify** at least two errors in their experimental design.
   (b) **Identify** all the variables that could affect the results of Catherine and Celine's experiment.
   (c) **Identify** any variables that Catherine and Celine do not need to control.
   (d) Write a step-by-step **outline** of the procedure that they could use to find out which cup keeps water hotter.

Catherine and Celine's experiment in progress



Analyse

7. Simon and Jessie conducted an experiment to find out how effectively two plastic cups maintain the temperature of near boiling water. Their data are shown right side.
   (a) **Construct** an appropriate graph to display the data.
   (b) **Identify** which cup maintained the temperature of the water more effectively.
   (c) Estimate the temperature of the water in Simon's cup 15 minutes after timing commenced.
   (d) Use your graph to **predict** how long it would have taken the water in Jessie's cup to drop to a temperature of 20 °C.

Comparing plastic cups

Time (min)	Temperature (°C)	
	Simon's cup	Jessie's cup
0	90	90
10	47	58
20	29	39
30	22	31
40	20	26
50	20	23

Design

8. Design and carry out an experiment to investigate one of the following.
   - What conditions affect the time taken for seeds to germinate?
   - Which conditions lead to the fastest plant growth?
   - Which colour cloth is the warmest?
   - How can a vase of flowers be kept fresh longer?
   - Which brand of paper towel is the most absorbent?
   - What affects how quickly objects fall?
   - Which brand of batteries lasts the longest?

Investigate

9. The aim of this experiment is to find out whether distances are easier to judge with two eyes than just one. You can do this by shooting for goal with a basketball or netball from a particular spot under three conditions:
   - left eye closed
   - right eye closed
   - both eyes open.

   To produce reliable results, more than one person should take the shooting test and each goal shooter should have several attempts.

   Plan and carry out your experiment. Write a formal report for the experiment including a table of results and a conclusion. In your discussion section:
   - **identify** the independent and dependent variables
   - **describe** the strategies you used to ensure that this was a fair test.

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Complete this digital doc: Worksheet 1.7: Fair testing (doc-12351)

1.7 Famous scientists

Science as a human endeavour

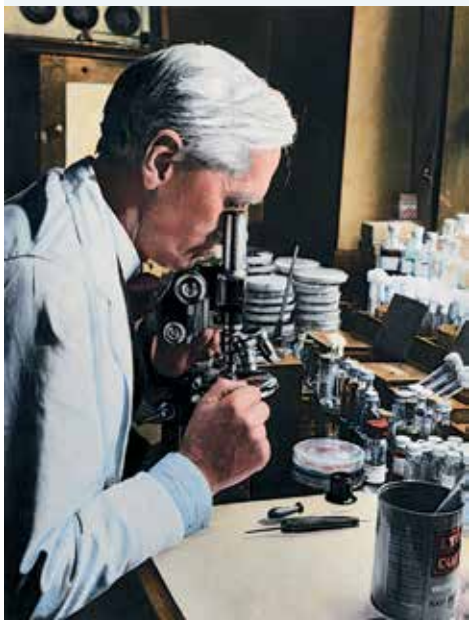
1.7.1 Meet some famous scientists

Many of the important scientific discoveries of the past began as questions, observations and experiments from famous scientists such as Alexander Fleming, Benjamin Franklin, Louis Pasteur, Albert Einstein, Galileo Galilei, Marie Curie and Isaac Newton.

Although our knowledge of science is advancing every day, a number of fundamental scientific ideas were developed some time ago. As well as coming up with new theories and ideas, modern-day scientists build on the knowledge of pioneering scientists.

The following scientists have made significant contributions to the development of science in the past.

Scottish bacteriologist Alexander Fleming discovered the first antibiotic, which he called penicillin. He observed that a tiny piece of mould that had contaminated his experiment stopped the growth of bacteria.



1.7.2 Alexander Fleming

A scientific discovery can start from a simple observation. In 1928, Alexander Fleming made an accidental discovery that was to change medicine. He was working on a completely different experiment when he discovered that some mould spores in the air had contaminated a petri dish growing **bacteria**. He noticed that the bacteria had stopped developing where the mould had landed. The mould contained a substance called penicillin. Just over ten years later, Australian-born scientist Howard Florey and his colleagues successfully purified the mould so that it could be used as a commercial **antibiotic**. Penicillin was the first antibiotic to be used, and it is still used for the treatment of serious bacterial infections.

1.7.3 Benjamin Franklin

Artist's impression of Benjamin Franklin and his son performing the kite experiment



Many scientific theories are initially prompted by observations. From an observation, a scientist can create a hypothesis — an educated guess about what is happening.

Benjamin Franklin, a famous American scientist, observed lightning and developed a hypothesis that lightning bolts were actually powerful electric currents. To test his hypothesis, Franklin flew a kite during a thunderstorm in 1752. He attached a metal wire to the tip of the kite as a conductor, and a key to the string. When Franklin placed his knuckle near the key, he observed a spark jump from the key to the knuckle. The test result helped to confirm his hypothesis. Franklin was lucky to have survived his experiment — several other attempts at the kite experiment electrocuted other scientists! His work led to the invention of the lightning rod, which is a metal spike attached to the top of a building. When hit by lightning, the lightning rod diverts the electricity down the spike and to the ground (through the path of least resistance). This helped solve the problem of buildings catching fire after being struck by lightning.

1.7.4 Louis Pasteur

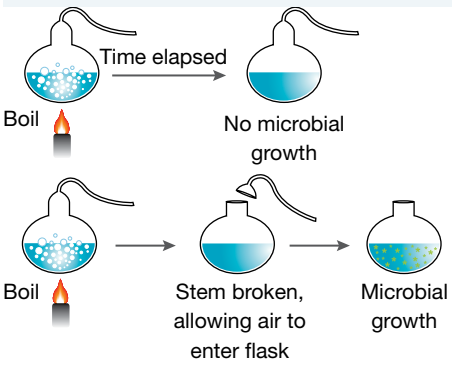
Louis Pasteur



To properly test an idea, a fair test of a hypothesis needs to be made. In a fair test, all factors should remain the same except one: the independent variable. In a simple experiment you change one independent variable at a time and observe what happens.

One of the greatest biologists of the nineteenth century was the French scientist Louis Pasteur. In 1859 he designed an experiment to test his hypothesis that bacteria growing on old food came from the air. At the time it was believed that life forms could generate spontaneously from non-living matter. Pasteur boiled meat broth in flasks to sterilise the flask and broth. Each flask had a thin, S-shaped neck that prevented dust in the air from entering the flask. He snapped off the neck of one of the flasks. The result was that micro-organisms grew in the meat broth in the flask open to the air, but not in the one with the S-shaped neck. He concluded that the micro-organisms in the air became trapped in the bent section of the neck. Because micro-organisms grew in the flask exposed to the air but not in the other, this experiment supported Pasteur's hypothesis that germs arrived from the air outside the flask.

Pasteur's experiment



A control is an experiment where each part is controlled or kept constant. Controls are used to compare against those experiments that have introduced a variable.

For example, in further experiments, Pasteur selected different variables. He exposed meat broth to clean mountain air and dirty city air. However, in this experiment Pasteur also included a control — broth that was not exposed to air. He found that a lot of bacteria grew in the dirty city air and only a small number of bacteria grew in the clean mountain air. The use of a control helped Pasteur determine that the appearance of bacteria must have had something to do with air, because bacteria grew only in the broth exposed to the air.

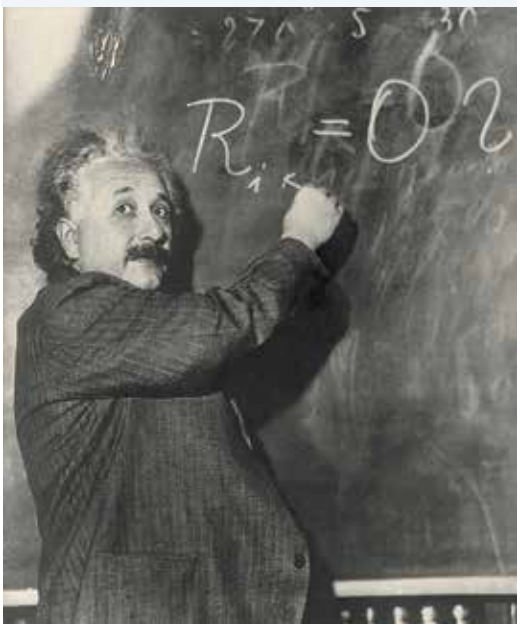
1.7.5 Albert Einstein

Albert Einstein was born in Germany in 1879. At 26, he began to publish his ideas on science, and he won the **Nobel prize** for physics in 1921.

One of Einstein's most recognised equations is $E = mc^2$. This rule describes how a large amount of **energy** (E) can be released from a small amount of **matter** (of **mass** m). For example, this equation shows that the amount of energy released when a mass equivalent to that of a golf ball is converted into energy is enough to power the lights of the Sydney Cricket Ground, and keep them running continuously for over 50 years.

Although his research and calculations were used in the development of the atomic bomb, Einstein himself was a pacifist, strongly against the use of nuclear weapons.

Albert Einstein writing an equation on a blackboard



Albert Einstein was one of the greatest thinkers in science history. His theories form the basis of a large portion of modern physics, particularly in the study of the universe.

1.7.6 Galileo Galilei

Galileo Galilei was born in Italy in 1564. In his younger days he studied physics and mathematics. In 1609, Galileo used his technical and mathematical skills to build his own telescope. He was the first person to use a telescope to study the night sky. In 1610 he published the book *Starry Messenger*. In it he claimed to have seen mountains on the moon and four small bodies orbiting Jupiter, and to have demonstrated that the Milky Way was made up of stars. In 1632, Galileo published work supporting the theory of Copernicus that the sun, not the Earth, was the centre of our galaxy. Galileo was found guilty of **heresy** (contradicting the church) and sentenced to life imprisonment, but he served the sentence under supervision in his home. He died in January 1642.

1.7.7 Isaac Newton

Sir Isaac Newton was born in England in 1642. He attended Cambridge University, but much of his work was done at home when Cambridge was closed for two years due to the plague. He is well known for his law explaining **gravity**, his laws of motion, his study of light, and for inventing **calculus** (a branch of mathematics).

A unit of force, the **newton**, has been named after him. Newton died in London in March 1727. Much of modern physics is based on his work.

Marie Curie conducting an experiment.



1.7.8 Marie Curie

Marie Curie was born in Warsaw in 1867. She studied mathematics and physics. In 1903, she shared the Nobel prize in physics with her husband Pierre Curie and Antoine Henri Becquerel for their work studying **radiation**. In 1911, she won the Nobel prize in chemistry for discovering the **elements** radium (used in the treatment of cancer) and polonium. Curie was the first person ever to win the Nobel prize twice, and the first woman ever to win.

Curie was a great humanitarian. She promoted the medical uses of radiation and X-rays. During World War I she created 'X-ray vans' and travelled to where soldiers needed medical help. When Curie died in July 1934, her body had been severely affected by the radiation she had been working with.

1.7 Exercises: 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 important observation that Alexander Fleming made that led to the development of the first antibiotic.
2. **Recall** the hypothesis regarding lightning that Benjamin Franklin put forward.
3. **Outline** the scientific discoveries that Sir Isaac Newton made.
4. **Explain** what the equation $E = mc^2$ represents. What did this scientific discovery lead to?
5. **Describe** how the work of Marie Curie is important in medical science today.

Think

6. **Identify** the senses that Franklin used to make observations during his kite experiment.
7. **Identify** the control that Louis Pasteur used in his experiment. Why was it important in helping to support his hypothesis?
8. Use the **Louis Pasteur** weblink in the Resources tab to learn about a process he invented to extend the life of liquids. What is this process called? How is it used today?

INVESTIGATION 1.12

Stopping the growth of bacteria

AIM: To investigate whether preservatives can stop the growth of bacteria

You will need:

chicken stock cube
vinegar
beaker (1 L)
salt
hot tap water (750 mL)
masking tape
stirring rod
pen or marker
3 beakers (250 mL)
teaspoon

- Place a chicken stock cube in a 1 L beaker and add 750 mL hot tap water.
- Stir the solution with a stirring rod until it is consistent.
- Pour 200 mL of the mixture into each of three 250 mL beakers.
- Add one teaspoon of vinegar to one small beaker and use the pen and masking tape to label the solution 'vinegar'.
- Add one teaspoon of salt to another small beaker and label the solution 'salt'.
- Label the third beaker 'control'.
- Place the three small beakers on a warm windowsill for two days.

Discussion

1. Salt is one of the most widely used of all food preservatives. Suggest a hypothesis relating to salt that could be tested by this experiment.
2. Observe the three solutions after 5–7 days. Large amounts of bacteria make the solutions go cloudy. Describe the degree of cloudiness of each solution and record this in a suitable table.
3. Which preservative was the most effective at stopping bacterial growth?
4. What role did the control play in this experiment?
5. Was your hypothesis supported by the results of this experiment? Explain.

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Explore more with this weblink: Louis Pasteur

learnon

1.8 Project: An inspiration for the future

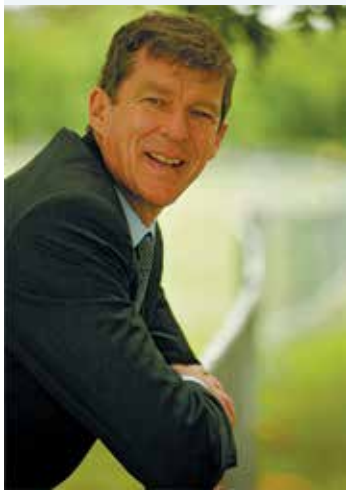
Scenario

The Florey Medal was established in 1998 by the Australian Institute of Policy and Science in honour of the Australian Nobel Prize-winning scientist Sir Howard Florey, who developed penicillin. It is awarded

biennially to an Australian biomedical researcher for significant achievements in biomedical science and human health advancement.

Imagine that a new panel is formed to establish an award for outstanding science students. This panel wishes to name the medal after an Australian scientist who provides the greatest inspiration for young people considering a future career in science. After months of consultation, the panel has narrowed the choices down to the following:

Ian Frazer (1953–): Immunologist



Fiona Wood (1958–): Plastic surgeon and burns specialist



David Unaipon (1872–1967): Inventor



Peter Doherty (1940–): Veterinarian and immunologist



Andrew Thomas (1951–): Astronaut



Graeme Clark (1935–): Otolaryngeal surgeon and engineer



Fred Hollows (1929–1993): Ophthalmologist



Your task

You will create a podcast of between eight and ten minutes' duration that is in the format of an interviewer discussing with a number of different people which of these scientists would be the best choice to name the medal after. The interviewees (played by your group members) should be people who would be likely to have an interest or stake in the award. Examples could include a member of the medal panel, a government minister, the head of a university science or science education department, a high school science teacher, or even a high school science student. Each interviewee should have their own preference as to which scientist should be selected and at least four scientists should be discussed during the interview.

SUGGESTED SOFTWARE

- ProjectsPLUS
- Word or other word processing software
- Excel or other spreadsheet software
- Internet access

1.9 Review

1.9.1 Study checklist

The use and influence of science

- **identify** some of the disciplines of science and some associated occupations **1.2**

The laboratory

- select and assemble the appropriate equipment to perform an investigation, including safety equipment **1.3**
- **describe** ways to reduce the risk to yourself and others when working in the laboratory **1.3**

Investigating

- use a range of equipment for collecting data accurately, including digital technologies such as data loggers **1.4**
- record observations and measurements accurately over a number of trials, using appropriate units for measured quantities **1.4**
- make inferences and testable hypotheses in light of observations made **1.4–1.6**
- use diagrams to present information clearly **1.5**
- use a range of text types appropriately, including procedure, discussion and explanation **1.5**
- **organise** and present data clearly using tables **1.5**
- select and draw the appropriate type of graph (column graph, pie or line graph) to convey information and relationships clearly **1.5**
- **extract** information from a variety of graph types, including column, pie and line graphs **1.5**

Designing investigations

- **outline** a logical procedure for undertaking a range of investigations to collect data related to the stated aim and using the principles of fair testing **1.6**
- **identify** the dependent and independent variables when planning controlled experiments **1.6**
- **identify** in fair tests, variables to be controlled (held constant), measured and changed **1.6**
- check the reliability of gathered data and information by **comparing** them with other observations or data **1.6**

- assess the method used in an investigation and identify improvements to the method **1.6**
- **identify** trends, patterns and contradictions in collected data **1.5, 1.6**
- **identify** data that support or discount a hypothesis **1.6**
- draw conclusions from experimental results and develop predictions based on those conclusions **1.6**

The nature and development of science

- use examples to show how scientific knowledge changes as new evidence becomes available **1.7**
- use examples to show how some scientific discoveries have significantly changed people's understanding of the world **1.7**

Individual pathways

ACTIVITY 1.1
Investigating
doc-10529

ACTIVITY 1.2
Analysing investigations
doc-10530

ACTIVITY 1.3
Designing investigations
doc-10531

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FOCUS ACTIVITY

Create a multimedia presentation or play to **explain** to your classmates how to safely light a Bunsen burner and heat the contents of a test tube.
Access more details about focus activities for topic in the Resources tab (doc-10528).

1.9 Review 1: Looking back

assessON

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.

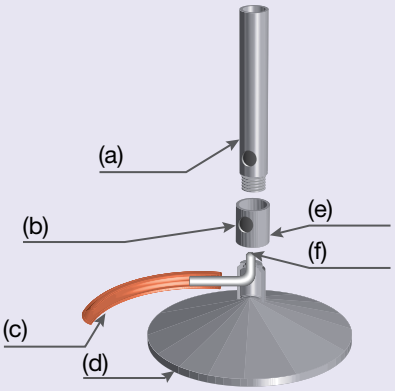
1. Match the following scientists with their work.

Scientist	Work
(a) Physicist	A Investigates how rocks and mountains form
(b) Chemist	B Studies living things
(c) Biologist	C Explains things like movement, heat and light
(d) Astronomer	D Studies how substances react with others
(e) Earth scientist	E Studies the night sky

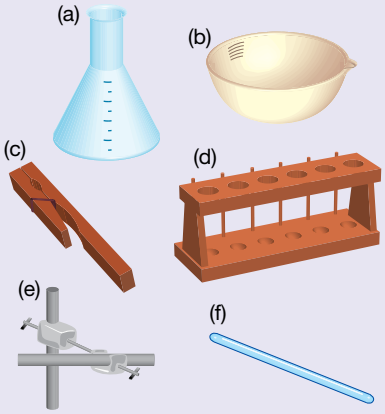
2. Match the scientist with the discovery in the list below.

Scientist	Discovery
(a) Isaac Newton	A Lightning bolts are electric currents.
(b) Louis Pasteur	B Micro-organisms are carried in the air.
(c) Marie Curie	C Four moons that orbit Jupiter
(d) Galileo Galilei	D Penicillin
(e) Alexander Fleming and Howard Florey	E Gravity
(f) Benjamin Franklin	F Radium

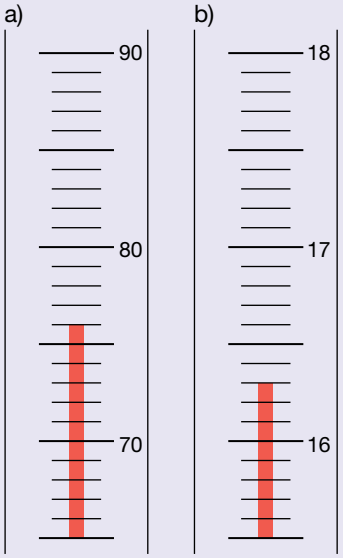
3. Copy this diagram of a Bunsen burner and complete all of the missing labels.



4. Name these pieces of equipment and **describe** what they are used for.



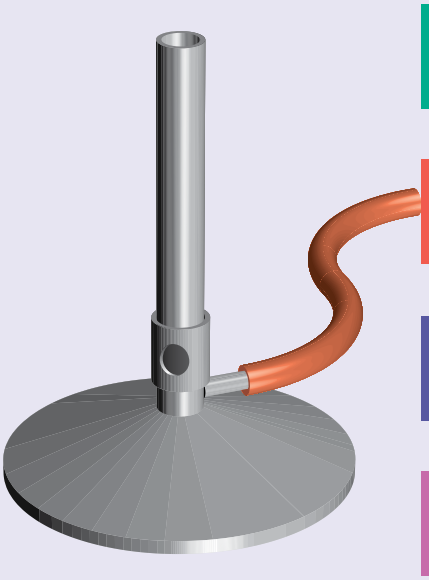
5. **Identify** the temperature measured by each of the thermometers shown below.
6. List two safety rules and **explain** why they are important.



7. Rewrite the following sentences correctly by selecting the appropriate words in *italics*.
   (a) When lighting a Bunsen burner, light the match *before/immediately after* turning on the gas.
   (b) When using a thermometer to measure the temperature of a liquid as it is heated, place the bulb of the thermometer *on the bottom/near the centre* of the beaker.
   (c) When heating a test tube, hold the test tube using *tongs/a test-tube holder* at the *top/middle* of the test tube and *keep it steady/move it back and forth* over the flame.

8. The steps used to light a Bunsen burner can be displayed as a flow chart, as shown below. Use the information in the flow chart to **construct** a storyboard with six scenes to show how a Bunsen burner is lit correctly and safely. (See page 693 to learn how to use storyboards.)

LIGHTING A BUNSEN BURNER



Place the Bunsen burner on a heatproof mat.

↓

Check that the rubber tubing is connected properly to the gas tap.

↓

Ensure that the airhole is closed.

↓

Light the match.

↓

Hold the burning match just above the top of the barrel.

↓

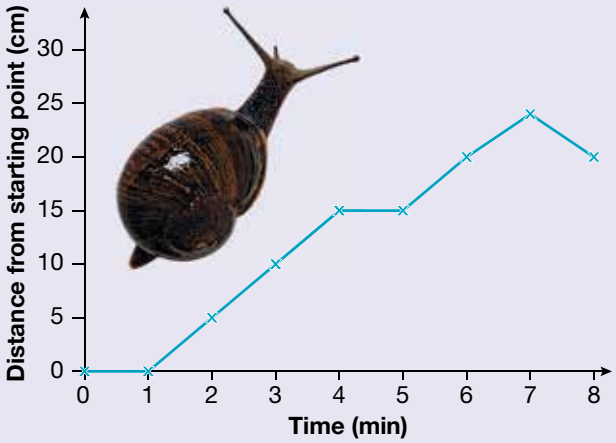
Open the gas tap.

9. **Construct** a table with three columns headed 'Observation', 'Hypothesis' and 'Prediction'. In the table, write each of the statements below under the correct heading and in their correct sequence, so that a scenario is followed across each row.
   - I am afraid of heights.
   - A snail has eaten holes in the leaves of my African violet plant, but hasn't touched the flowers.
   - I will experience similar symptoms if I stand at the top of another building, a cliff or bridge.
   - My CD has been damaged.
   - Snails eat leaves, but not flowers.
   - My CD skips (briefly stops playing) when I play it.
   - When visiting the top deck of Sydney Tower, my heart started beating more quickly and loudly, my palms sweated and I felt a bit dizzy.
   - If I put a different flowering plant in place of my African violet each night, the snail will eat only the leaves of each plant, and ignore the flowers.
   - If I try playing my CD in someone else's CD player, it will still skip.

10. Four students each measured the temperature in the same classroom using a thermometer. Their results were:
    (a) **Construct** a bar graph of these results.
    (b) **Propose** some possible reasons for the differences between measurements.

Student	Temperature (°C)
1	23.5
2	24.0
3	25.0
4	22.0

11. The following graph shows how far from the starting point a snail moves in an experiment.



(a) **Calculate** how far from the starting point the snail was 7 minutes after timing began.
(b) During what times did the snail not move at all?
(c) What does the graph tell us about the snail's movement between 7 and 8 minutes after timing began?
(d) **Propose** why a smooth line was not drawn in this graph.

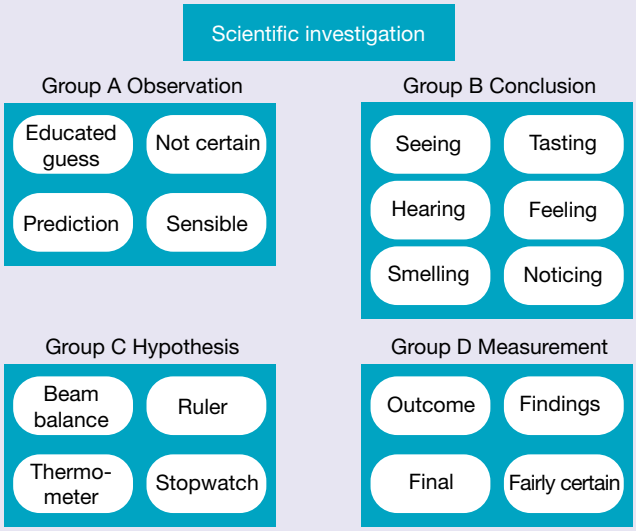
12. Look at the photograph at right.
(a) What *qualitative* observations do you think the scientist can make from this experiment?
(b) **Propose** two different *quantitative* observations the scientist might make from this experiment.
(c) **Propose** what might be the aim of this experiment.



13. The following table shows the winning times for the men's 400 m freestyle swimming event. The data are from various Olympic games from 1908 to 2012.
(a) Are data available for each Olympics every 4 years?
(b) **Construct** a line graph of the times for the men's 400 m freestyle over these years. Take into account your answer to part (a).
(c) Use your graph to estimate the winning time for this event in the 1956 Melbourne Olympic games.
(d) **Discuss** how the winning times have changed over the 112-year period.
(e) Suggest some reasons for the change in winning times.
(f) **Discuss** how you believe the times for the men's 400 m freestyle might change over the next 40 years.

Year	Name, country	Time (min:s)
1908	Henry Taylor, Great Britain	5:36.8
1920	Norman Ross, USA	5:26.8
1932	Buster Crabbe, USA	4:48.4
1948	Bill Smith, USA	4:41.0
1960	Murray Rose, Australia	4:18.3
1972	Bradford Cooper, Australia	4:00.27
1984	George DiCarlo, USA	3:51.23
1996	Danyon Loader, New Zealand	3:47.97
2000	Ian Thorpe, Australia	3:40.59
2004	Ian Thorpe, Australia	3:43.10
2008	Taehwan Park, Korea	3:41:86
2012	Yang Sun, China	3:40:14

14. The affinity diagram below organises some of the ideas used by scientists into four groups. Each category name is a single word and represents an important part of scientific investigations. However, the category names have been jumbled up. What are the correct categories for groups A, B, C and D? (See page 689 to learn how to use affinity diagrams.)

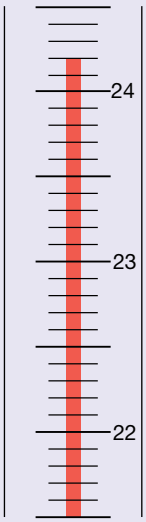


15. **Construct** a storyboard that tells the story of the main events in the life of one of these famous scientists. (See page 693 to learn how to use storyboards.)
    (a) Albert Einstein
    (b) Sir Isaac Newton
    (c) Marie Curie
    (d) Louis Pasteur

Test yourself

1. **Identify** which of the following is an important safety rule in science.
   A When smelling chemicals, place your nose carefully over the container.
   B Dispose of all materials in the rubbish bin.
   C When reading the volume of a liquid, always read the bottom of the meniscus.
   D Point test tubes away from your eyes and away from your fellow students. **(1 mark)**
2. Some important steps in using a Bunsen burner are listed below but the sequence is incorrect.
   1. Light a match and hold it over the barrel.
   2. Adjust the flame by moving the collar until the airehole is open.
   3. Connect the rubber hose to the gas tap.
   4. Turn on the gas tap and a yellow flame will appear.
   5. Close the airhole of the Bunsen burner collar.

   The correct sequence is
   A 3, 5, 4, 1, 2.
   B 3, 5, 1, 4, 2.
   C 5, 3, 4, 1, 2.
   D 1, 3, 5, 4, 2. **(1 mark)**
3. Equipment used for measuring the volume of liquids includes
   A conical flask, beaker, measuring cylinder.
   B measuring cylinder, crucible, beaker.
   C watchglass, filter funnel, conical flask.
   D evaporating basin, test tube, beaker. **(1 mark)**
4. A thermometer scale is shown below. The temperature indicated is
   A 26.0 °C.
   B 24.4 °C.
   C 24.2 °C.
   D 24.5 °C. **(1 mark)**



5. Luke was sick and tired of being bitten by mosquitoes. He counted several bites each evening when he sat outside to have dinner. He had heard that a burning citronella candle was a good way to keep mosquitoes away. Design an experiment to test Luke's idea. **Identify** the independent and dependent variables and the controlled variables needed to make this a fair test. Suggest a control for your experiment. **(6 marks)**

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Complete this digital doc: Focus activity (doc-10528)

Complete this digital doc: Worksheet 1.8: Investigations puzzle (doc-12352)

Complete this digital doc: Worksheet 1.9: Investigations summary (doc-12353)

TOPIC 2
Cells — the building blocks of life

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.

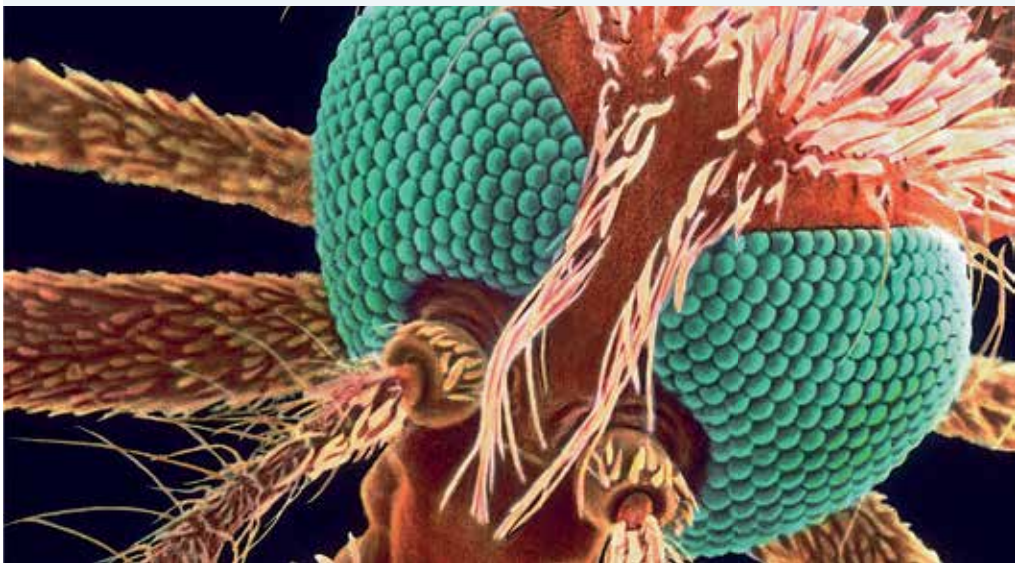
2.1.1 Why learn this?

Animals, plants and other living things are made up of tiny cells. Before the microscope was invented, no one had seen or knew about cells, so the development of the microscope had a huge impact on the study of biology. It allowed biologists to zoom in on life and observe cells, and it made it possible to see microscopic organisms that no one knew existed. The photo below shows an insect's head viewed using an electron microscope.

LEARNING SEQUENCE

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Electron micrograph of an insect's head

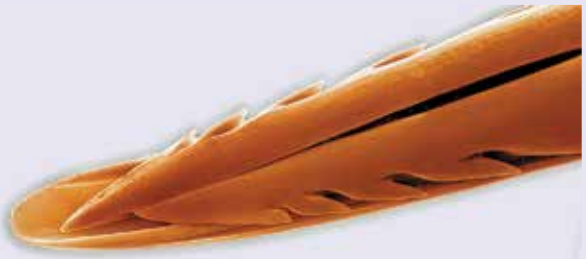


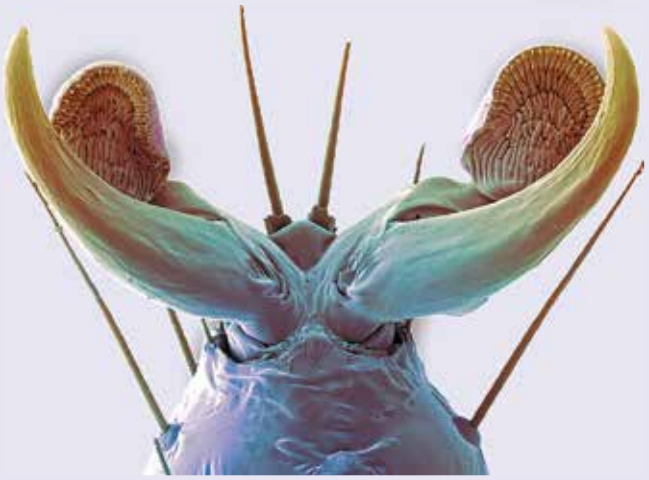
Who am I?

Microscopes are responsible for opening a whole new world to us. They have allowed us to see beyond our own vision. The more developed these microscopes become, the more detail and wonder we are able to observe — but often, rather than answering our questions, they provide us with many more.

The three photos show parts of different animals. They were taken with a scanning electron microscope, which allows us to see more detail of the surface of specimens.

1. Look carefully at the photos of each animal part and think about:
   (a) what they could be
   (b) what they may do
   (c) which animals they may belong to.
2. Discuss your suggestions with your partner, writing all of the details that you have both observed on a sheet of paper.
3. Two of these photos show parts of one type of animal, and the other one is of a different animal. Does that information change the way that you look at the details? Which animal do you think two of the parts belong to? Brainstorm to decide which animal the other part could belong to.
4. Suggest other sorts of information that may be helpful in determining which animals these parts belong to and what they are used for.







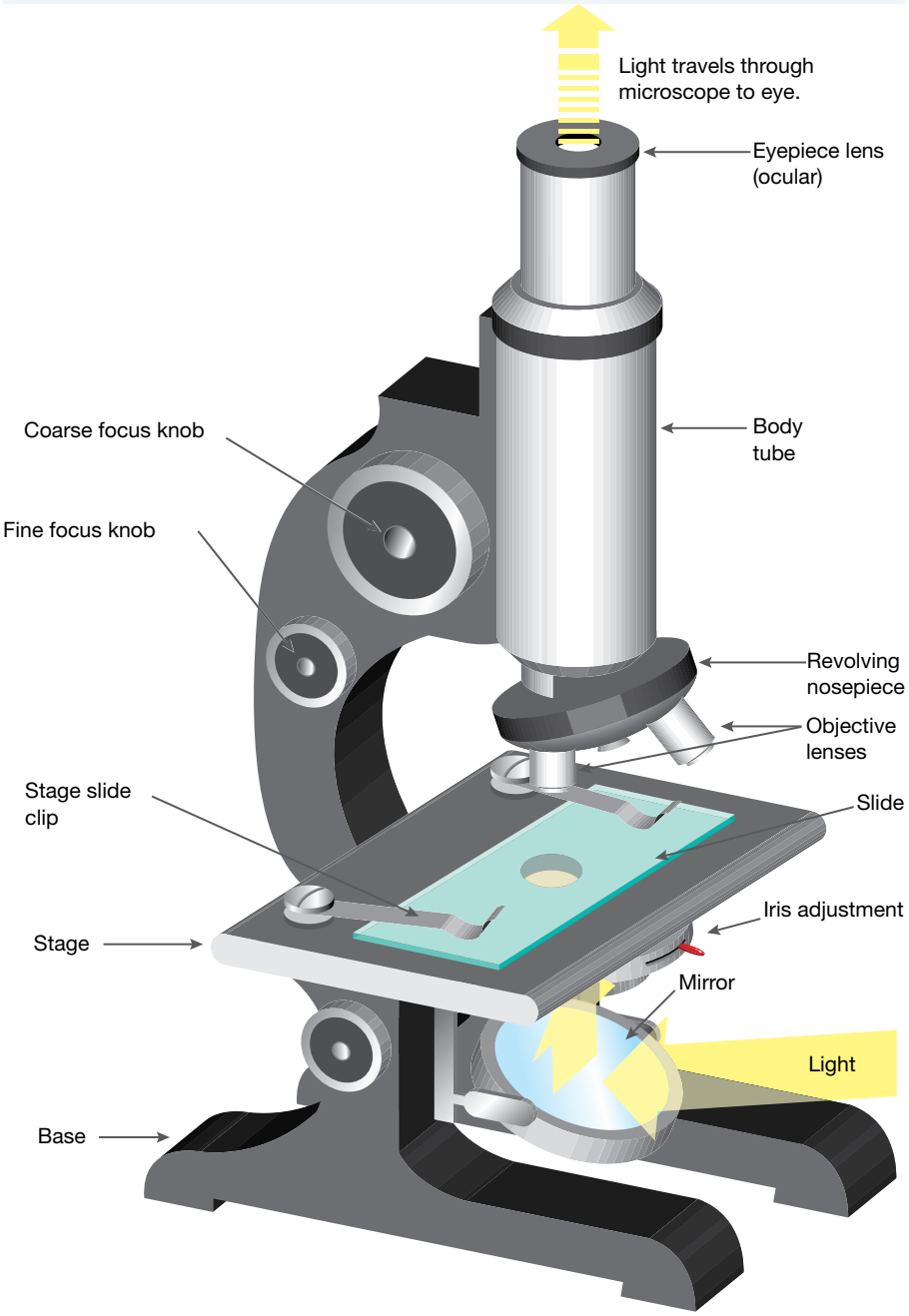
2.2 Using a microscope

2.2.1 The compound light microscope

Microscopes make small objects appear bigger. With a microscope you can zoom in and see the cells that make up living things. You can see the features of tiny creatures such as fleas and ticks. Even everyday objects, such as paper and onion skin, can take on a completely different appearance when viewed under a microscope.

The type of microscope most commonly used in schools is the compound light microscope. These microscopes use light and a number of lenses to form an image. The diagram at right shows a typical school microscope. The specimen (the object being observed) is placed on a rectangular piece of glass called a microscope slide. The specimen needs to be very thin so that light can pass through it. A small, thin piece of glass called a coverslip is placed on top of the specimen. Light is made to pass through the object and the glass lenses, which bend the rays of light. A magnified image of the part of the specimen directly under the objective lens is formed. The microscope at right has only one eyepiece; it is a monocular microscope. Some school microscopes have two eyepieces; they are called binocular microscopes. Some of the microscopes at your school may have built-in lights. These microscopes do not have a mirror at the bottom; they have a light instead.

Monocular light microscope



2.2.2 How much bigger?

The eyepiece and objective lenses are both magnifying lenses. Most microscopes have a selection of objective lenses, and a revolving nosepiece allows the user to switch from one objective lens to another and thus change the magnification. You can calculate the magnification by multiplying the eyepiece magnification by the objective lens magnification. This is shown in the box below.

Eyepiece magnification: ×10
Objective lens magnification: ×20
Total magnification = 10 × 20
= ×200

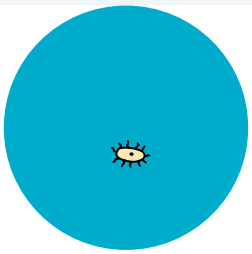
Typical school microscopes can magnify up to 400 times, although greater magnification is possible using very high-quality light microscopes. It is important to note that changing the objective lens does not change the size of the image; it just shows a tinier part of the specimen at a greater magnification.

Microscope measurements

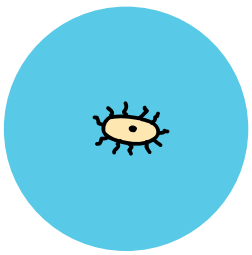
Microscopes can zoom in on tiny objects, so tiny in fact that it is not practical to express their size in metres, centimetres or even millimetres. The measurements of objects viewed under a microscope are usually expressed in microns or micrometres.

1 micron or micrometre (μm) = 0.000 001 m
= 0.001 mm

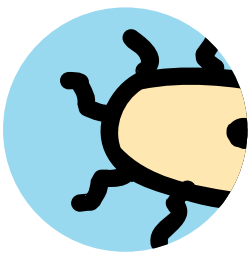
At higher magnification, the field of view is smaller; the microscope zooms in to a tinier section of the specimen.



Field of view 4 mm (4000 μm) magnification ×40



Field of view 1.6 mm (1600 μm) magnification ×100



Field of view 0.4 mm (400 μm) magnification ×400

Rules for handling a microscope

- Always use two hands when carrying a microscope: one on the arm of the microscope and the other under the base.
- Place the microscope securely on a flat surface, away from the edge.
- Never shine sunlight directly up the microscope tube. You could damage your eyes.
- Use only lens tissues to clean microscope lenses; never use your fingers.

More hints for using a microscope

- Look down the microscope with one eye, but keep both eyes open — don't squint.
- Begin focusing a microscope on the lowest magnification.
- Focus a microscope by beginning with the coarse focus. Look from the side and adjust the objective lens so that it is just above the microscope slide.
- Turn the coarse focus knob to move the tube up until the object comes into view.
- Turn the fine focus to make the image of the object as clear as possible.

Take a photo

You can take photos of microscopic objects using a digital eyepiece. This is a special digital camera that works with a microscope. Instead of looking through the eyepiece to see the image, the digital eyepiece

is connected to a computer and the image can be viewed on a computer screen. The image can be saved, annotated and manipulated in the same way as any digital photo.

INVESTIGATION 2.1

Getting into focus with an 'e'

AIM: To practise focusing a microscope

You will need:

1 cm square piece of newsprint containing the letter 'e'
monocular light microscope
microscope slide
clear sticky tape
1 cm square piece of colour picture from a magazine or newspaper
a hair
salt
digital eyepiece (optional)

- Carefully stick the 1 cm square of newsprint onto a clean microscope slide using sticky tape.
- Using the guidelines above, focus on the paper using the coarse focus knob and the lowest power objective lens (smallest magnification).
- Carefully move the slide until you have a letter 'e' in focus.
- Change to a higher level of magnification by rotating to a higher power objective lens.
- Using sticky tape, stick a small section of a colour photograph, a hair, some salt crystals and any other objects your teacher has provided onto microscope slides. View each specimen under the microscope on low power.
- If your school has access to one or more digital eyepieces, you or your teacher may be able to take photos of the objects as well.

Discussion

1. In which direction did the paper under the microscope move when you moved the slide
   (a) towards you or
   (b) to the left?
2. What does the letter 'e' look like under the microscope? Draw a pencil sketch of what you see.
3. Record the magnification that you are using, and estimate how much of the viewed area is covered by the letter 'e' at this magnification.
4. Suggest what the letters 'P' and 'R' would look like under the microscope. Sketch your predictions, and then view examples of these under the microscope. Were your predictions correct?
5. Describe the appearance of the small section of colour photograph when viewed with the microscope.
6. Draw a sketch of the hair and salt crystals viewed with the microscope. Remember to record the magnification.
7. List some advantages and disadvantages of using a digital eyepiece.

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. Write the following steps in the correct order.
   (a) Adjust the fine focus.
   (b) Place the slide on the stage.
   (c) Twist the revolving nosepiece to switch to the high-power objective lens.
   (d) Adjust the coarse focus.
   (e) Ensure that the lowest power objective lens is selected.
   (f) Use the fine focus knob again if necessary to focus the image.

2. Match each microscope part with its function.

Part	Function
(a) Stage	A Makes large adjustments to the distance between the stage and the objective lens; brings the image into focus
(b) Eyepiece lens	B Holds the slide in place
(c) Coarse focus knob	C Where the slide is placed
(d) Fine focus knob	D Used to adjust the amount of light reaching the eyepiece
(e) Stage slide clip	E Thin piece of glass where the specimen is placed
(f) Mirror	F The part you look through; magnifies the image
(g) Iris adjustment	G Magnifies the image
(h) Slide	H Directs the light towards the specimen
(i) Revolving nosepiece	I Makes small adjustments to the distance between the stage and the objective lens; brings the image into focus
(j) Objective lenses	J Can be turned to change objective lens

3. Use a digital camera or webcam to take a photo of your school microscope.
   (a) Label the parts of the microscope.
   (b) **Compare** your school microscope with the diagram on page 48.

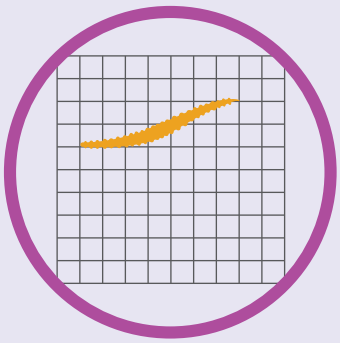
Think

4. When focusing the microscope, you should always start with the objective lens as close to the microscope slide as possible; then use the coarse focus to slowly move them apart. **Explain** why this reduces the risk of damaging the slide and the objective lens.
5. **Discuss** whether a photo or a diagram is more effective for communicating information about the structure of a specimen.
6. Copy and complete the table below.

Ocular (eyepiece) lens	Objective lens	Total magnification
×5	×5	×25
×5	×10	
×10	×4	
×10		×100
	×40	×400

7. A piece of thread has a width of 0.1 mm.
   (a) Convert this measurement to µm.
   (b) The thread is viewed with a hand lens that provides ×4 magnification. **Calculate** how wide the thread appears when viewed with the lens.
   (c) **Calculate** how wide the thread appears when viewed with a microscope that has a ×10 eyepiece lens and a ×4 objective lens.
8. The diagram on the next page shows a grid viewed under ×40 magnification. This grid is also called a graticule; it is on a glass disc that is often inserted into the eyepiece of a microscope to help measure small objects. The lines are 100 µm apart. The diagram also shows a worm at ×40 magnification.
   (a) Estimate the field of view (the diameter of the circle).
   (b) Estimate the length of the worm in millimetres and in micrometres.

(c) The magnification is changed to ×400. Are the following statements true or false?
(i) The field of view is bigger.
(ii) The worm appears larger.



Investigate

9. Most school microscopes are parfocal. Do some research and **define** this term.
10. Find out why some microscopes have an oil immersion lens.
11. Test your knowledge of the functions of different parts of a microscope by completing the **Microscope parts** interactivity in the Resources tab.
12. Use the **Virtual light microscope** weblink in the Resources tab to practise your microscope skills.
13. *Extension*. Use the **Microscope measurements** weblink in the Resources tab to learn more about estimating the size of an object viewed under the microscope.

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Try out this interactivity: Microscope parts (int-0205)
Explore more with this weblink: Virtual light microscope
Explore more with this weblink: Microscope measurements

2.3 The right tool for the job

2.3.1 Thick or thin?

There are many different types of microscopes and choosing the right type for a particular task is important. At school you may have two kinds of light microscope to choose from, depending on whether you need to observe a thin specimen or the surface of a thicker object. Universities and other research facilities have access to electron microscopes. These provide greater magnification and detail than light microscopes.

The microscope shown on page 48 is suitable for viewing only very thin objects that can be mounted on a slide. A stereomicroscope is useful to provide a magnified view of the surface of thicker objects such as rocks, crystals, insects and small flowers. These microscopes do not provide as much magnification but they have the advantage that the specimen does not need to be sliced thinly.

The photo at right shows a handheld USB microscope. Like the stereomicroscope, it can be used to view the surface of thick objects, but it plugs into a computer. The image is displayed on the computer screen and can be saved and edited. These devices are cheaper and more portable than stereomicroscopes, but they cannot be used without a computer.

Handheld USB microscope



2.3.2 Electron microscopes

Typical school microscopes can magnify up to 400 times. The best light microscopes can magnify up to 2000 times at the most. This is sufficient to see bacteria, but viruses are so tiny

that they cannot be seen even with the best quality light microscope. An electron microscope is required. These use a beam of particles called electrons, rather than light, to produce an image with up to 2 million times magnification. Electron microscopes are very expensive and take up a lot of space (often an entire room), so they are found mainly in universities and other research facilities. Preparing specimens for viewing is tricky. A specimen needs to be dehydrated and may be coated with a thin layer of metal, so it is not possible to observe living organisms. The images produced (called electron micrographs) are black and white, although sometimes colours are added later to make particular features stand out or enhance the appearance of the image.

There are two types of electron microscope. Scanning electron microscopes (SEM) scan the surface of an object and can produce an image of the surface of the object. The images on page 47 were produced by an SEM. In a transmission electron microscope (TEM), the electrons pass through a thin section of an object and so the image is a cross-section of the specimen.

INVESTIGATION 2.2

Using a stereomicroscope

AIM: To practise using a stereomicroscope

You will need:

stereomicroscope
handheld USB microscope (optional)
selection of small objects (e.g. small flowers, alum crystals, pebbles, grass, fabric, seeds)

- Use the stereomicroscope to view each of the objects.
- Sketch each object. Remember to record the magnification on your sketch.
- If possible, use the handheld USB microscope to take photos of the objects.

Discussion

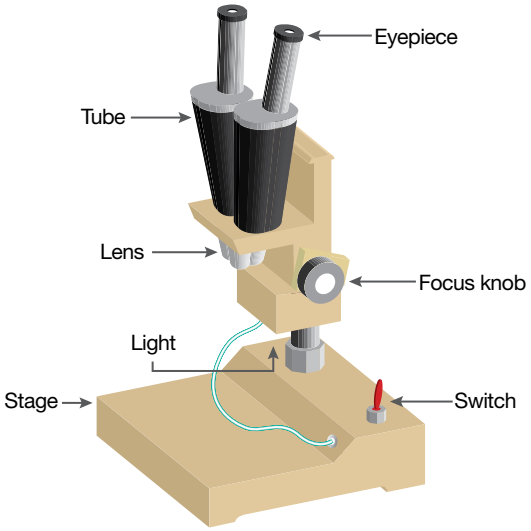
1. For each object you viewed using the stereomicroscope, describe some of the features that can be seen more clearly with the microscope.
2. What are the advantages of using a handheld USB microscope rather than a stereomicroscope?
3. In which situations would a stereomicroscope be more useful than a USB microscope?

2.3.3 Comparing microscopes

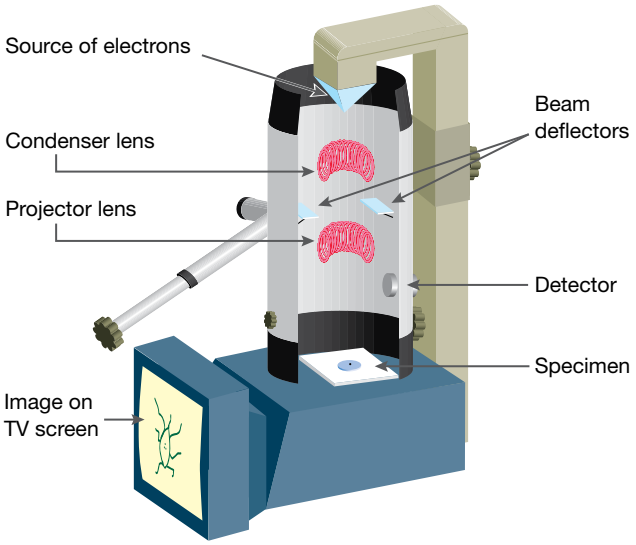
Some comparisons between light microscopes and electron microscopes

Type of microscope	Magnification (how many times bigger)	Resolution (how much detail we can see)	Advantage(s)	Disadvantage(s)	Examples of detail that can be seen
Light microscope	Up to ×2000	Up to about 500 times better than the human eye	Samples prepared quickly; coloured stains can be used; living cells can be viewed	Limited visible detail	Bacteria; shape of cells; some parts inside cells
Electron microscope	×2 000 000	Up to about 5 million times better than the human eye	High magnification and resolution	Very expensive; takes up a lot of space; preparation of specimens is difficult; images produced are black and white; only dead specimens can be viewed	All parts of cells; viruses

Stereo light microscope



Scanning electron microscope



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. **Identify** which of the following statements are correct. Rewrite any incorrect statements to make them correct.
   (a) An electron microscope can produce greater magnification than a light microscope.
   (b) A handheld USB microscope can be used without a computer.
   (c) To view an object with a stereomicroscope, it needs to be sliced very thinly and mounted on a slide.
   (d) Electron microscopes produce colour images.
   (e) It is possible to observe living cells with a light microscope.
2. **Compare** the following pairs of microscopes.
   (a) Light microscope and electron microscope
   (b) Monocular microscope and stereomicroscope
   (c) Scanning electron microscope and transmission electron microscope.

Think

3. Stereomicroscopes are also called dissection microscopes. **Explain** why this type of microscope is often used for dissections.
4. **Explain** why adding colour to an electron micrograph can help biologists communicate information about the image.
5. **Deduce** why it is not possible to observe live specimens with an electron microscope.
6. Use the **Virtual scanning electron microscope** weblink in the Resources tab to view electron micrographs of a range of specimens. In what ways are the images produced by an electron microscope different from those produced by a light microscope?
7. The electron microscope can produce greater magnification and resolution than a light microscope. Use the **Magnification/resolution** interactivity in the Resources tab to **define** these terms.

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Explore more with this weblink: Virtual scanning electron microscope

Explore more with this weblink: Resolution vs Magnification

2.4 A whole new world!

Science as a human endeavour

2.4.1 Tiny living things

The invention of the microscope just over 400 years ago had a huge impact on Biology. It became possible to see cells, the building blocks of living things, and whole kingdoms of previously undiscovered living things were uncovered. As microscopes improved, biologists were able to learn a whole lot more about cells and microbes.

The microscope made it possible to see the cells that make up living things. Samples of plant matter, when viewed under the microscope, appeared to be made up of small boxes. Early microscopes did not give the high-quality images that are produced with today's microscopes, but they made it possible to see tiny living things that are too small to distinguish with the naked eye. Observing pond water under the microscope revealed that it was teeming with organisms made up of just one cell: unicellular organisms. Similarly, when vinegar, saliva or plaque scrapped from someone's teeth were observed with a microscope it was revealed that they, too, contained single-celled organisms. Later, the electron microscope was developed. This type of microscope allows even greater magnification and has enabled scientists to observe the structures of the tiniest bacteria and even viruses.

INVESTIGATION 2.3

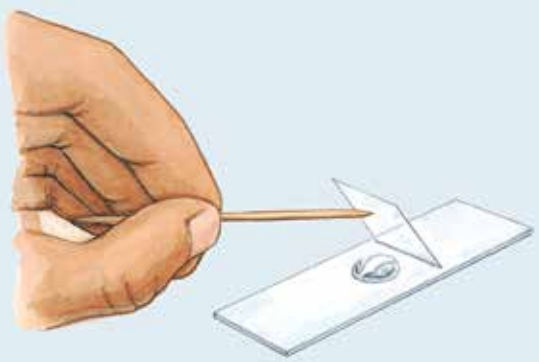
Observing microscopic organisms

AIM: To observe some microscopic organisms

You will need:

light microscope
microscope slide (Well slides work best for this experiment but, if these are not available, flat slides are also suitable.)
coverslip
pipette
sample of pond water
toothpick
(optional) digital eyepiece
(optional) culture of live microscopic organisms (e.g. Paramecium, Amoeba, *rotifer)*

- Place one drop of pond water on the microscope slide (if it is a well slide, you may be able to use two or three drops).
- Place a coverslip over the drop of water. The diagram on the right shows how to use a toothpick to avoid air bubbles when lowering the coverslip.
- Draw up a results table in your notebook with the following headings: 'Diagram', 'Description', 'Name'.
- Use the microscope to observe the slide. Draw and describe any organisms you see. Use the **Pond life** weblink in the Resources tab to identify the organisms.
- If you have a digital eyepiece available, you may be able to take photos or a video of the organisms in the pond water.
- Remove the coverslip, and rinse and dry the slide. Then prepare a new slide using a culture of live microscopic organisms (if available). Observe these and draw and describe them in your results table.



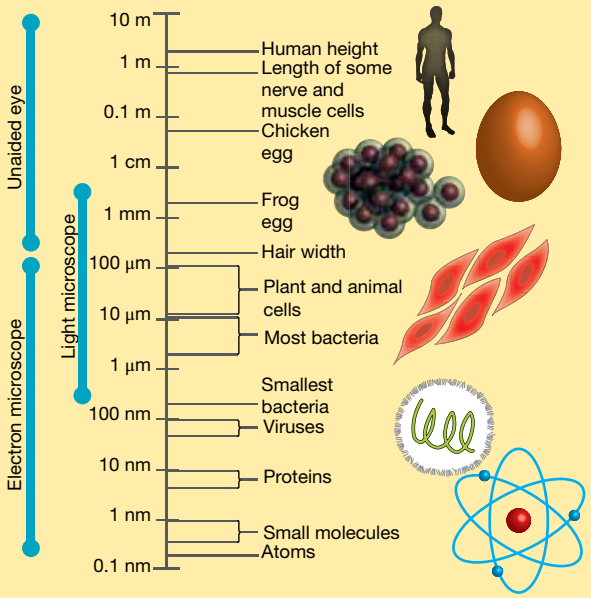
Discussion

1. Did any of the organisms move? Describe their movements.
2. *Paramecium* is an organism made of just one cell. A culture of *Paramecium* can be kept alive by adding a few grains of cooked rice and leaving the lid unscrewed so air can get in.
   (a) Why is it important to allow air into the jar?
   (b) Why does the rice help keep the *Paramecium* alive?
3. What are the advantages of observing live cultures of organisms (rather than a prepared slide)?

HOW ABOUT THAT!

Van Leeuwenhoek was the first person to observe bacteria, red blood cells, sperm cells and muscle fibres under the microscope. He started out his working life as a draper, selling fabric. He used magnifying lenses to count the threads in cloth. He became interested in microscopy after seeing a book by Robert Hooke that contained illustrations and descriptions of specimens observed using a microscope. Van Leeuwenhoek made many microscopes over his lifetime and he observed all kinds of specimens including plaque that he scraped off his own and other people's teeth. He was meticulous in recording his observations and made detailed descriptions of specimens. He was not very good at drawing though and he employed an illustrator to complete many of his diagrams. Some of the personal attributes that made him a successful microbiologist included natural curiosity and very good eyesight, the patience and persistence needed to grind the high-quality lenses he used to make his microscopes, and the attention to detail required to painstakingly record all his observations.

1 millimetre = 1/1000th of a metre
1 micrometre = 1/1 000 000th of a metre
1 nanometre = 1/1 000 000 000th of a metre



Timeline showing the development of microscopes and cell theory

1665
Robert Hooke used the microscope at right to observe a great variety of things and published his observations and drawings in a book entitled *Micrographia*. When he observed cork under the microscope, he noticed that it appeared to be made up of small boxes that he called cells. This is still the name we use today to refer to the building blocks of living things.





1831
Robert Brown was a botanist. He made observations of plants under the microscope. He identified a structure in plant cells that he called the nucleus.

1660 1670 1680 1690 1700 1710 1720 1730 1740 1750 1760 1770 1780 1790 1800 1810 1820

1670
Anton van Leeuwenhoek made many microscopes of his own design, such as the one shown at right. His microscopes were small devices with a single lens and were held up to the eye. Van Leeuwenhoek examined a great variety of specimens including plaque scraped from teeth, blood, semen and saliva. He discovered what he called 'animalcules' — tiny living things not seen without the aid of a microscope. We now call these micro-organisms.



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. Match each scientist with his achievement.

Scientist	Achievement
(a) Robert Brown	A Built the first electron microscope
(b) Anton van Leeuwenhoek	B Noted that cork was made up of box-shaped structures that he called cells
(c) Ernst Ruska	C Observed a structure in cells that he called the nucleus
(d) Robert Hooke	D The first to observe unicellular organisms

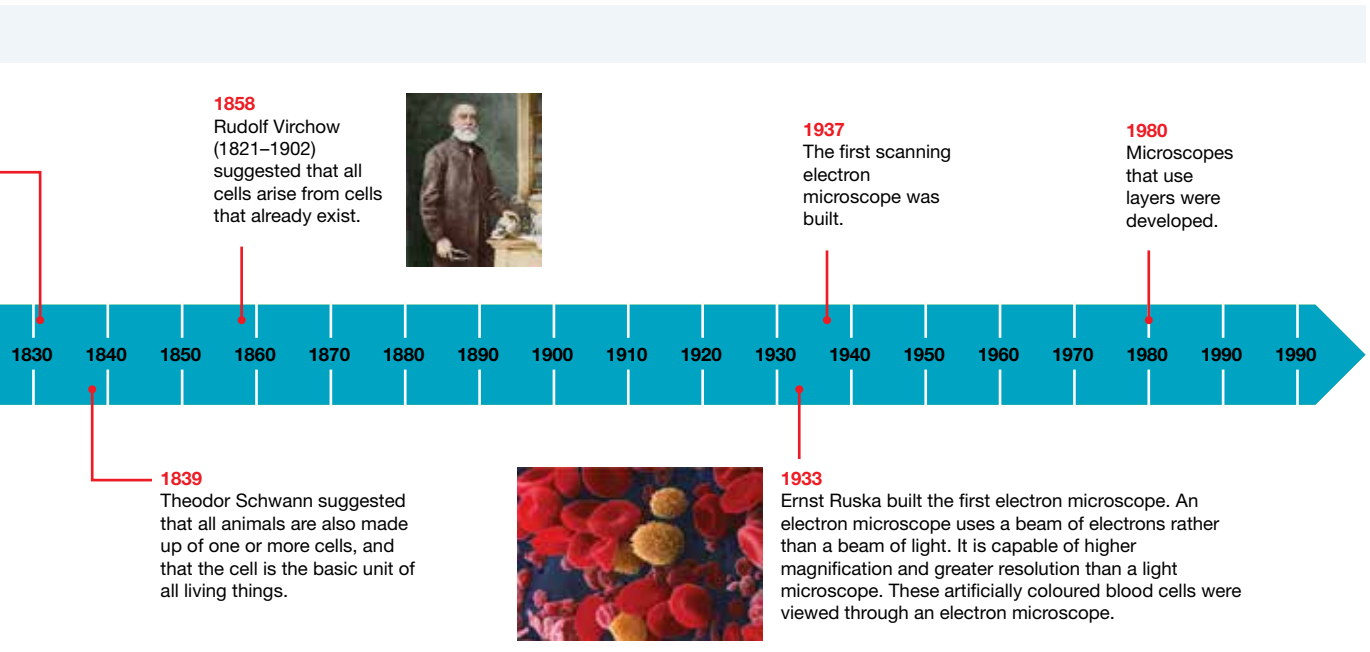
2. **Describe** the appearance of the cells that Hooke observed in thin sections of cork.
3. Do all cells look the same?

Think

4. Assess the significance of the invention of the microscope on Biology.
   Anton van Leeuwenhoek was very curious. **Explain** how this contributed to his success as a microbiologist.
5. Use the timeline on these two pages to answer the following questions.
   (a) In which year did Hooke use the term 'cells' to describe his observations of cork slices?
   (b) What did Virchow suggest in 1858?
   (c) In which substance did Leeuwenhoek discover bacteria?
   (d) When did Ruska invent the electron microscope?

Investigate

6. Research one of the scientists in the timeline above and present your information in a poster. Discuss this with your classmates.
7. Prepare a fact sheet about one of the organisms you observed under the microscope. Include the following information: name, photo or diagram, size, how it obtains nutrients and interesting facts.
8. Use the diagram on page 56 to answer the following questions.
   (a) **Compare** the sizes of animal cells and bacteria.
   (b) **Identify** three things that can be seen with an electron microscope but not a light microscope.



(c) **Deduce** whether you would need a microscope to see a frog's egg.
(d) Complete the table below.

Object	Size in microns	Size in millimetres 1 micron = 0.001 mm	Size in metres 1 micron = 0.0000001 m
Plant and animal cells			
Hair (width)			
Frog egg			

9. Visit the **Robert Hooke** weblink in the Resources tab and investigate why he used the term 'cells' for the little box-shaped structures he observed in cork. What did people think living things consisted of before Hooke's discovery of cells? Write a story about your findings.
10. Use the **Moth** weblink in the Resources tab to compare the images of a moth produced by Galileo's and Culpeper's microscopes. Describe some differences between the images produced by the two microscopes.

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Watch this eLesson: Robert Hooke and cells (eles-1780)
Complete this digital doc: Worksheet 2.1: History of the light microscope (doc-12354)
Explore more with this weblink: Robert Hooke
Explore more with this weblink: Pond life
Explore more with this weblink: Moth

2.5 Living things are made of cells

2.5.1 Different types of cells

When we look at living things under the microscope, we can see that they are made up of cells and that the cells contain 'little organs' or **organelles**. There are different types of organelles and each organelle has a particular function or job. Plant and animal cells appear quite different and contain different organelles.

Animal cells can have many different shapes and sizes but they share some common features. They are enclosed by a **cell membrane** that controls the movement of substances in and out of the cell. Inside the cell membrane there is a runny, jelly-like substance called **cytosol** and a darker area called the **nucleus**. The nucleus is the control centre of the cell. It contains DNA, a chemical substance that holds the instructions for making particular proteins. These proteins determine what the cell does. For example, in some of the cells of your pancreas, sections of DNA that code for the manufacture of a protein called insulin are switched on, so these cells make insulin. There are other structures in the cytosol. Many of these are too small to see with a school microscope. **Mitochondria** are organelles that can be seen only with a very high-quality light microscope or an electron microscope. In the mitochondria, glucose reacts with oxygen to release energy. This process is called **respiration**. The cytosol and the organelles that it contains (except the nucleus) make up the cytoplasm.

2.5.2 Plant cells and animal cells

Plant cells tend to be larger and have a more regular shape with some straight edges. This is because they contain a large, water-filled **vacuole** and are enclosed by a rigid **cell wall**. The vacuole stores water and minerals. Plant cells contain cytosol, a nucleus, mitochondria and a cell membrane, just like animal cells. They also contain green organelles called **chloroplasts**. These are the site of **photosynthesis**, a process that

Chloroplasts
Chloroplasts are the oval-shaped organelles found only in plant cells. Chloroplasts contain a green substance called **chlorophyll**. Chloroplasts use energy from the sun to make food. Not all plant cells contain chloroplasts. They are found only in leaf and stem cells.

Vacuole
The vacuole is an organelle used to store water and dissolved substances. Vacuoles can look empty, like an air bubble. Plant cells usually have one large vacuole. The mixture inside a plant's vacuoles is called **cell sap**. The red, blue and violet colours that you often see in plant leaves and flowers are due to the substances stored in vacuoles. Most animal cells don't have vacuoles.

Cell wall
The tough covering around plant cells is the cell wall. It gives plant cells strength and holds them in shape. Cell walls are made of a substance called **cellulose**. Water and dissolved substances can pass through the cell wall. Animal cells do not have a cell wall.

Plant cell

Cell membrane
The thin layer that encloses the cytoplasm is the cell membrane. It keeps the cell together and gives it its shape. Some substances, such as water and oxygen, can pass through the cell membrane but other substances cannot. The cell membrane controls what enters and leaves the cell.

Animal cell

Nucleus
The nucleus is the control centre of the cell. It contains DNA in the form of chromosomes and it controls what the cell does and when.

Cytosol
The jelly-like substance inside cells is the cytosol. It contains many important substances, such as glucose, that are needed for chemical reactions that occur inside cells. (*Note:* Cytoplasm = cytosol + all organelles except nucleus)

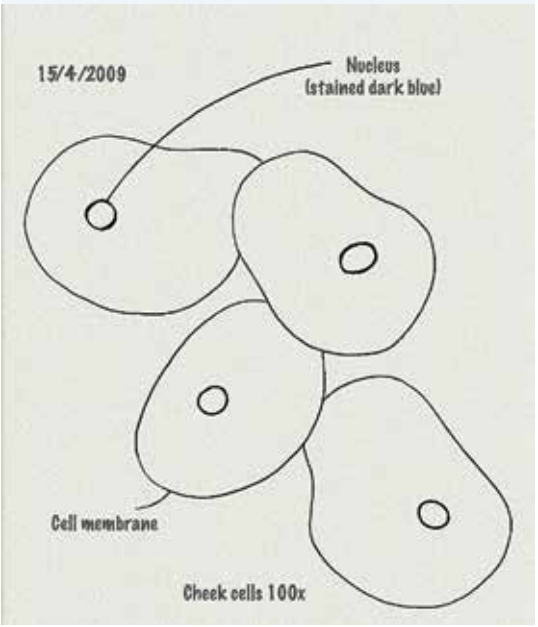
uses energy from the sun to convert carbon dioxide and water into glucose and oxygen.

2.5.3 Sketching what you see under the microscope

Some points to remember

1. Use a sharp lead pencil.
2. Draw only the lines that you see (no shading or colouring).
3. Your diagrams should take up about a third to half a page each.
4. Record the magnification next to each diagram.
5. State the name of the specimen and the date of observation.
6. A written description is also often of considerable value.
7. When you are viewing many cells at one time, it is often useful to select and draw only two or three representative cells for each observation.

An example of a sketch of a microscope specimen



Staining a specimen

Many objects are colourless when viewed down the microscope, so specimens are often stained to make them easier to see. Methylene blue, iodine and eosin are some examples of commonly used stains. Each stain reacts with different chemicals in the specimen. For example, iodine stains starch a blue-black colour. Take care when using these stains, because they can stain you as well!

INVESTIGATION 2.4

Making a wet mount and applying a stain

AIM: To prepare and stain a specimen on a microscope slide

You will need:

microscope
clean microscope slide
coverslip
dropper bottle of water
forceps (tweezers)
scalpel
toothpick
small section of a peeled onion
celery stick
banana
blotting paper

CAUTION: The scalpel has a sharp blade. Handle it with care.

- Use the dropper to put a drop of water on a microscope slide.



- Use a scalpel to peel a small piece of the very thin, almost transparent onion skin from the inside surface of the onion.



- Use the forceps to put the piece of the onion skin into the drop of water on the microscope slide.



- Place a coverslip over the top of the water containing the onion skin. Use a toothpick to lower the coverslip gently to avoid air bubbles. Use blotting paper to soak up any excess water outside the coverslip.





- Observe the onion epidermis under the microscope, first on low power, and then increase the magnification.
- Prepare another slide of onion skin but, instead of putting a drop of water on the slide, put a drop of methylene blue on the slide.
- Draw a sketch showing a few cells. Label any parts you can identify.
- Use the steps outlined in this investigation to prepare each of the following slides.
  - Celery epidermis (the outer 'skin' of the celery stem) with no stain (water only)
  - Celery epidermis, stained with methylene blue
  - A very small piece of banana, squashed, with no stain
  - Squashed banana stained with iodine
- View each slide under the microscope and draw a labelled sketch.

Discussion

1. Compare the cells of the onion epidermis and the celery epidermis. Which organelle can you see in the celery cells but not in the onion cell? Suggest a reason for this.
2. Why are stains used?
3. Which cell part(s) take up methylene blue?
4. Iodine has a yellow-brown colour. It combines with starch to produce a dark blue colour. Does banana contain starch?

2.5 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.

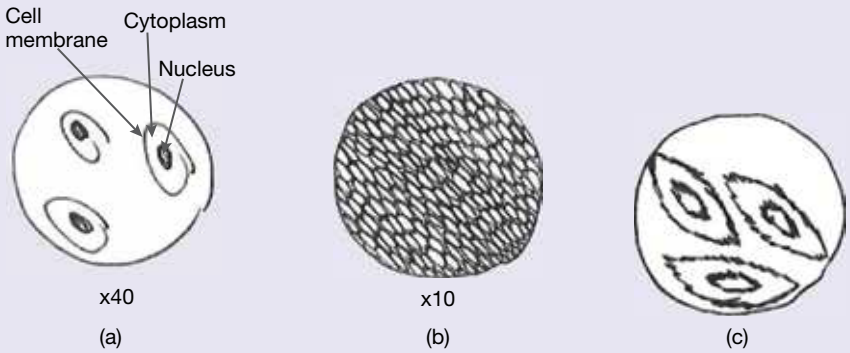
Remember

1. **Define** the term 'organelle'. List two examples of organelles.
2. **Distinguish** between cytoplasm and cytosol.
3. **Construct** a table summarising the function of the following cell parts: cell membrane, nucleus, chloroplast, cell wall, vacuole, mitochondria.
4. **Outline** the role of DNA in cells.
5. **Recall** what cell walls are made of.

6. Use a table to **compare** plant and animal cells. Include information about the organelles found in each type of cell, their size (refer to page 56) and shape.
7. **Recall** three things you must remember to do when sketching what you see under the microscope.
8. (a) **Define** the term 'stain'.
   (b) **Explain** why stains are used.
   (c) Give two examples of stains you have used in class.

Think and reason

9. **Outline** why most plants are green.
10. The cellulose cell wall that surrounds plant cells makes these cells rigid. **Explain** why animals may find it difficult to move if their cells had cell walls.
11. **Outline** why it is important for animals to be able to move whereas plants can survive without moving about.
12. **Describe** what is wrong with each of the diagrams shown below.



Investigate

13. View some prepared slides of human cheek cells and leaf epidermis under the microscope. Draw labelled diagrams of each type of cell.
14. Watch the **Inside cells** animation to learn about cells and organelles.
15. Use the **Cell drag and drop** weblinks in the Resources tab to practise labelling cells.

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Watch this eLesson: Inside cells (eles-0054)

Complete this digital doc: Worksheet 2.2: Cells and microscopes (doc-12355)

Complete this digital doc: Worksheet 2.3: Preparing a stained wet mount (doc-12356)

2.6 What a cell needs!

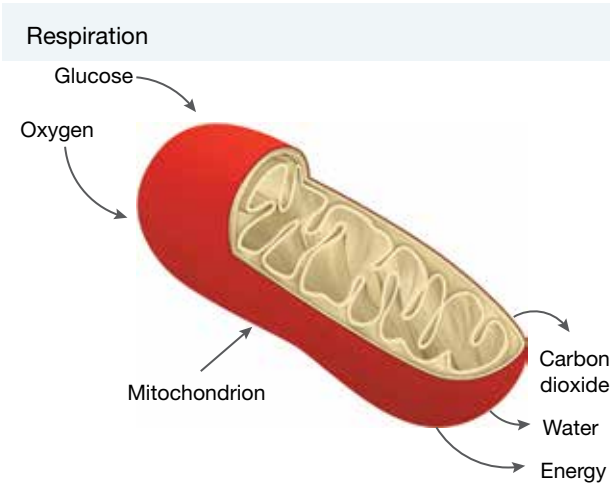
2.6.1 Respiration

In order to survive, cells need to go through various processes, including respiration, which take place inside cells. Therefore, the substances needed for these processes must enter the cells and harmful waste products need to be removed.

All living things need energy to survive. There are organelles in cells called mitochondria. Respiration, a chemical process that releases energy, occurs in the mitochondria. Respiration is a chemical reaction where

glucose, a type of sugar, reacts with oxygen to produce a gas, called carbon dioxide, and water. It can be summarised by the following equation:

glucose + oxygen → carbon dioxide + water



Respiration is a very important process because this is how living things convert the energy locked up in glucose into a useful form. Cells that have a high demand for energy, such as muscle cells in animals, contain many mitochondria. Respiration takes place in the cells of animals, fungi, plants and many microscopic organisms. One important difference between animals and plants, though, is the source of glucose and oxygen that they use in respiration.

2.6.2 Where does the glucose come from?

Animals obtain the glucose needed for respiration by ingesting food. In humans and many other animals the food passes through a digestive system where the complex chemicals that make up the food are broken down into smaller chemicals, including glucose. The small chemicals pass through the walls of the small intestine and into the bloodstream and are delivered to all the cells of the body. The bloodstream thus brings glucose from the food we eat to the cells that need glucose for respiration.

Plants can make their own glucose. On page 59, we saw that plant cells contain chloroplasts where photosynthesis occurs. Photosynthesis produces glucose, so plant cells do not need to ingest food. The glucose they need for respiration is made from carbon dioxide and water, using sunlight as a source of energy. Photosynthesis can occur only when there is light. During the day, plants usually make more glucose than they need for respiration. Some of the glucose is converted to other chemicals, such as the cellulose that plant cell walls are made of. Some glucose is converted to starch and stored in various parts of the plant, including the roots. At night, the plant continues to carry out respiration. When it starts to run out of glucose, some of the starch is converted back into glucose so that respiration can continue.

Fungi break down other substances to obtain the glucose and other chemicals that they need.

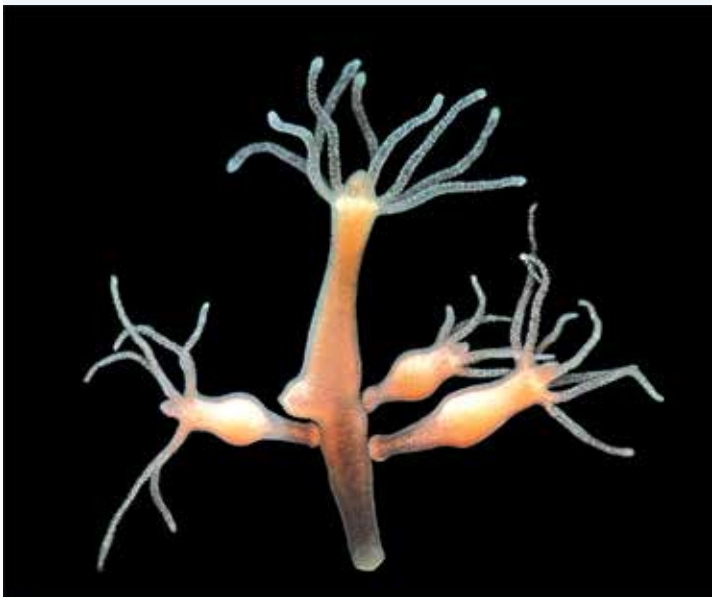


Fungi do not eat food either; nor do they carry out photosynthesis. They obtain glucose and the other chemicals they need for survival from the material on which they grow. The substances needed to break down this material move out through the cell membrane and cell wall of the fungus; the chemicals resulting from this breakdown that the fungus needs then move into the cells of the fungus.

2.6.3 What about the oxygen?

In animals, fungi and many microscopic organisms, the oxygen needed for respiration comes from the air or water in which they live. The hydra shown below is a tiny animal, about 1 cm long, that lives in rivers and streams. The water in which it lives contains small amounts of dissolved oxygen. The oxygen moves into the hydra through its skin. This is known as **diffusion**.

Some animals do not have lungs. Oxygen diffuses into a hydra over the entire surface of its body.

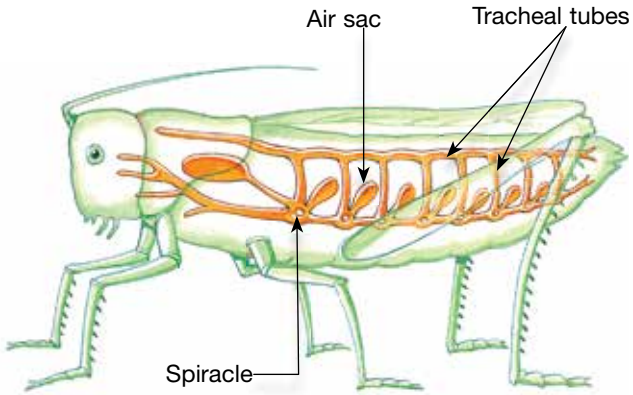


Larger animals need specialised structures to get the oxygen into their bodies. Fish and many other aquatic animals have gills to extract oxygen from their environment. Insects get oxygen into their bodies via little holes, called spiracles, along the sides of their bodies. These holes lead to tubes that bring the outside air into the body of the insect, so that oxygen can diffuse into the cells that need it.

Humans and other mammals have a complex respiratory system that includes lungs. Air is breathed into the lungs. Oxygen moves across the walls of the air sacs in the lungs and into the bloodstream so it can be delivered to cells.

Insects get oxygen into their bodies via small holes called spiracles, which can sometimes be seen as tiny dots along the sides of their bodies.





Plants carry out photosynthesis during the day. Oxygen is a waste product of photosynthesis so, during the day, plants make the oxygen that they need for respiration. The leaves of plants have small holes called stomates. Gases, including oxygen and carbon dioxide, can move in and out of leaves via these stomates.

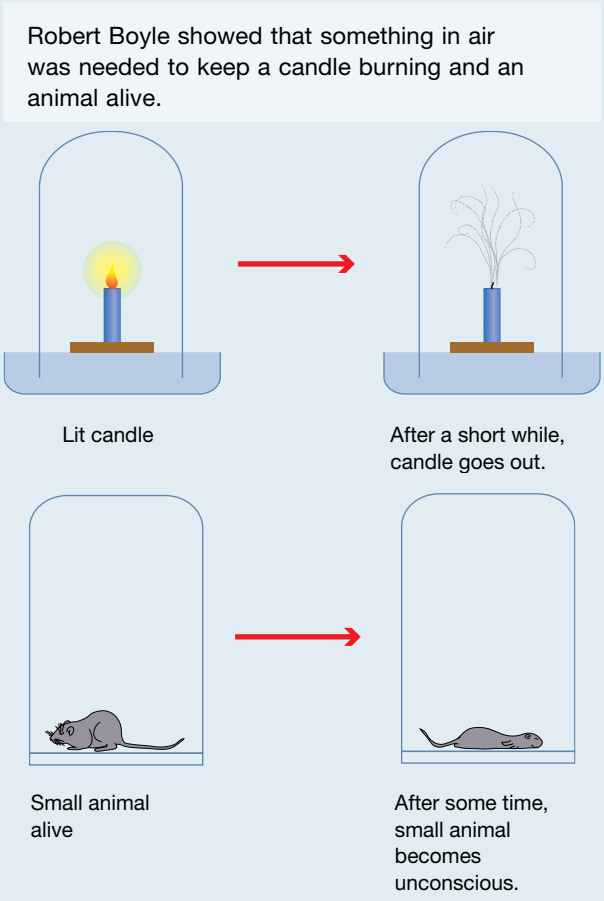
2.6.4 Dealing with waste

The products of respiration are water and carbon dioxide. Water is used in various processes in living cells, but carbon dioxide can be a problem if it builds up to high levels. Animal cells cannot use up the carbon dioxide produced in respiration, so it needs to be removed from the cells and taken out of the body. In simple animals, including the hydra shown above, carbon dioxide simply diffuses out of the animal over the whole surface of its body. In more complex animals, the carbon dioxide leaves the body in the same way that oxygen moves in, but in the opposite direction. In humans, carbon dioxide moves out of cells and into the bloodstream. It travels to the lungs, where it diffuses through the walls of the air sacs, and it is then breathed out.

2.6.5 A little history

How do we know about respiration and the need for oxygen to survive? It's all thanks to the work of some very clever scientists from the past. Some of their work is discussed on following pages.

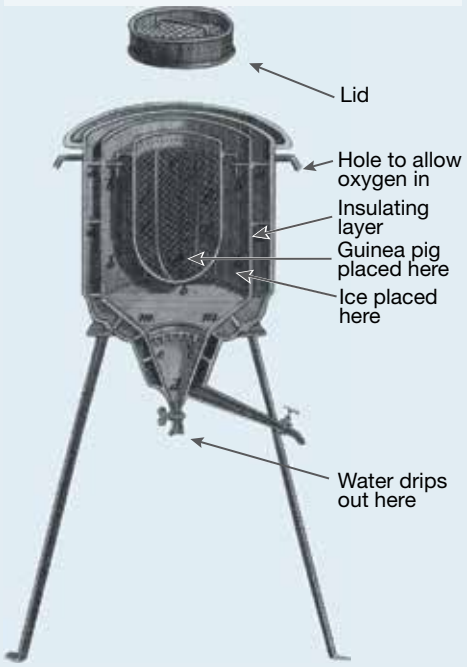
Robert Boyle (1627–91) showed that something in air was needed to keep animals alive as well as to keep a candle burning. He carried out experiments in which he put various items inside jars inverted over water to ensure that no air could enter the jar. When he placed a burning candle inside a sealed jar, the candle went out. When he placed a small animal inside the sealed jar, the animal became unconscious. If he put air back into the jar, the animal sometimes revived.



Lavoisier

Antoine Lavoisier (1743–94) also contributed to our understanding of respiration. He showed that respiration was a process that produces heat, just like burning (combustion). He placed a guinea pig in a **calorimeter**, a device designed to measure the amount of heat released when a substance burns. A picture of the calorimeter used by Lavoisier is shown below. Lavoisier measured the amount of ice that melted in order to calculate the amount of heat released by the guinea pig as it respired.

Lavoisier used this calorimeter (shown here cut away to reveal the inside) to show that respiration releases heat energy. He placed the guinea pig inside the basket and surrounded it with ice, which melted and ran out of the funnel.

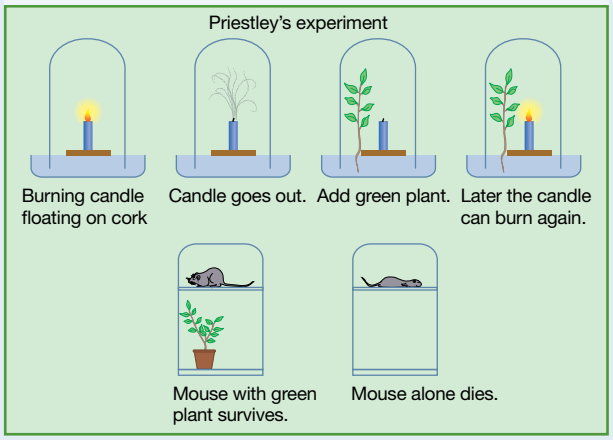


Priestley

Joseph Priestley (1733–1804) took Boyle's experiment one step further. Like Boyle, he put a candle in a jar inverted over some water and the candle went out. He then introduced a living plant inside the same jar without letting any air in. After a few days, he was able to relight the candle and found it could burn for a short time. This showed that the living plant could produce the substance that was needed for the candle to burn (oxygen).

Priestley also set up an experiment with an animal inside a sealed jar with a plant. In another sealed jar he placed the same animal but no plant. Only the animal living in the jar that contained the plant survived. The plant must have produced something that the animal needed to survive (oxygen again!).

Joseph Priestley showed that plants produce the substance needed to keep a flame burning and an animal alive.



INVESTIGATION 2.5

Candle in the jar

AIM: To demonstrate the relationship between oxygen and combustion

You will need:
birthday candle
Blu-Tack
heatproof mat
glass jars or glasses of different sizes (such as jam or instant coffee jars)
stopwatch
measuring cylinder
graph paper

- Using the Blu-Tack, attach the birthday candle to the heatproof mat.
- Light the candle.
- Invert one of the glass jars over the candle and time how long it takes for the candle to go out.
- Repeat this, using jars of different sizes.
- Measure the volume of each jar by filling the jar with water and emptying the water into a measuring cylinder.

Discussion

1. Draw up a table like the one below to record your results.

Jar number	Time taken for candle(s) to go out	Jar volume (mL)

2. Plot a line graph showing jar volume on the horizontal axis and the time taken for the candle to go out on the vertical axis.
3. Is there a relationship between the size of the jar and the time taken for the candle to go out? Explain your answer.

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. Write down the word equation for respiration.
2. **Identify** the part of the cell where respiration occurs.
3. (a) **Recall** the substances needed for respiration.
   (b) **Outline** how humans take these in.
4. (a) **Recall** the waste products formed by respiration.
   (b) **Outline** how humans get rid of one of these substances.
5. **Identify** which of the following statements are correct. Rewrite any incorrect statements to make them correct.
   (a) All living things respire.
   (b) Plants respire at night and photosynthesise during the day.
   (c) Respiration releases energy.
   (d) Photosynthesis releases energy.
   (e) The waste products from respiration are glucose and carbon dioxide.

(f) Photosynthesis produces carbon dioxide gas.
(g) When a candle burns, it uses up oxygen gas.
(h) Animals that live in water do not need oxygen to survive.

Think

6. Study the diagram on page 66 showing Priestley's experiment.
   (a) **Explain** why there was water at the bottom of the jar and in the container that the jar was sitting in.
   (b) If Priestley had tried to relight the candle as soon as he had put the plant in the jar, would it have stayed alight? **Explain** your answer.
   (c) If the plant was dead, would the experiment have worked? **Explain** your answer.
   (d) Would Priestley's experiment have produced the same results if it had been carried out inside a dark room? **Explain** your answer.
   (e) In the part of the diagram with the mice, which of the two jars (left or right) is the control?
7. Study the picture of Antoine Lavoisier's calorimeter on page 66.
   (a) How did Lavoisier ensure that oxygen could enter the chamber where the guinea pig was placed?
   (b) **Explain** why it was necessary to have very good insulation between the layer of ice and the outside of the container.
   (c) *Extension*. Ice melts at 0 °C. It takes 4.2 joules of energy to heat 1 mL of water by 1 °C. The ice started out at a temperature of −4 °C. After the guinea pig had been left in the calorimeter for 30 minutes, 50 mL of water was collected. **Calculate** the amount of heat released by the guinea pig.

Investigate

8. Lavoisier, Boyle and Priestley used animals in their experiments. What procedure must scientists follow today if they want to use animals in experiments? Justify why such procedures are necessary.
9. The type of respiration described on page 63 is aerobic respiration. Anaerobic respiration is another type of respiration. Use resource materials or the internet to find the answers to the following questions.
   (a) **Outline** the difference between aerobic and anaerobic respiration.
   (b) Write a word equation for:
      (i) the type of anaerobic respiration that occurs in your muscles when you sprint
      (ii) fermentation (another type of anaerobic respiration).
   (c) What is lactic acid? **Outline** why it is important to athletes.
   (d) What type of organisms carry out fermentation? **Identify** some foods and drinks made using fermentation as part of the manufacturing process.

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Complete this digital doc: Worksheet 2.4: Cellular respiration (doc-12357)

2.7 One cell or more?

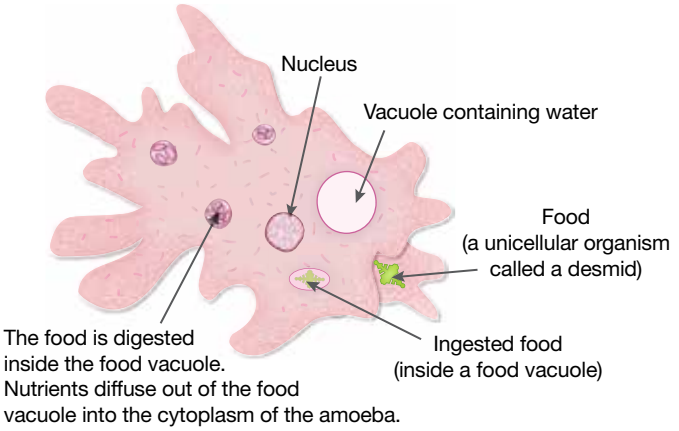
2.7.1 Introduction

Animals and plants are made up of many cells; they are **multicellular** organisms. Some microscopic organisms, including bacteria, are **unicellular**; they are made of just one cell. These organisms reproduce by dividing.

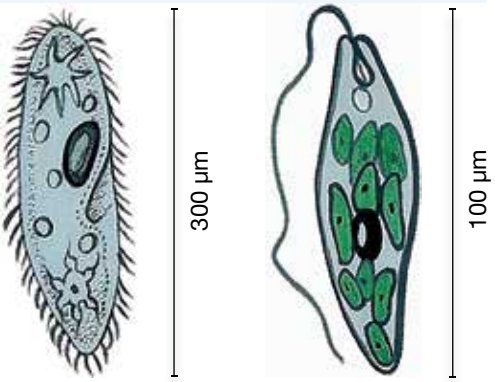
There are two main types of unicellular organisms: those that have a nucleus (the protists) and those that do not have a nucleus (mainly bacteria).

Examples of protists include *Amoeba, Paramecium* and *Euglena*. *Amoeba* look like blobs but they can move about and they can engulf food. *Paramecium* have small hairs that beat to enable them to move. *Euglena* are interesting because they can take in food (like animals) and also carry out photosynthesis (like plants), depending on the availability of food and sunlight.

An amoeba feeding



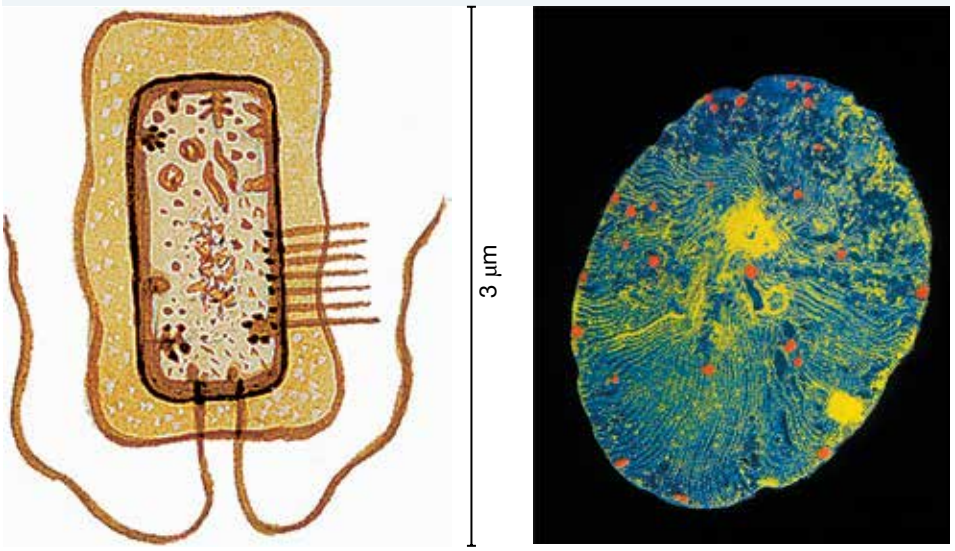
Protists have a nucleus; they include *Amoeba, Paramecium* and *Euglena*.



Paramecium *Euglena*

Examples of unicellular organisms that do not have a nucleus include bacteria, cyanobacteria and bacteria-like organisms that are believed to be similar to the very first life forms to have evolved on Earth.

Bacteria and cyanobacteria are unicellular organisms that lack a nucleus.



Bacterium Cyanobacterium

When an organism is made of only one cell, it is necessary for that cell to carry out all the jobs needed to keep the organism alive. The cell cannot specialise. You could compare this to a single-teacher school where one teacher has to teach all subjects, take phone calls, operate the canteen and write the weekly newsletter. The teacher would need to be able to do lots of things reasonably well, but she would not have time to become an expert at any one thing.

In multicellular organisms, on the other hand, certain cells can become specialised for a particular task. For example, red blood cells specialise in carrying oxygen around the body, and nerve cells specialise in transmitting messages from one part of the body to another.

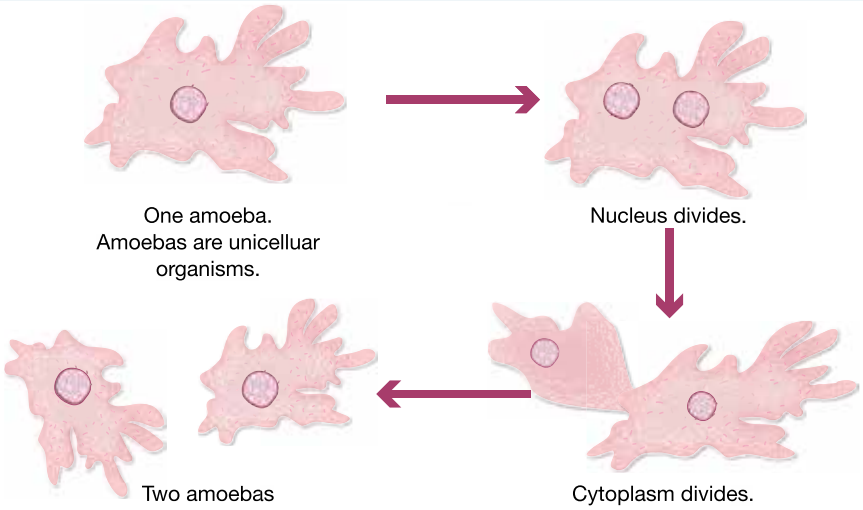
2.7.2 Binary fission

Unicellular organisms reproduce by dividing into two cells using a process called **binary fission**. First, the cell grows. When it reaches a certain size, it divides into two small cells, which in turn grow and

eventually divide. In unicellular organisms that have a nucleus, the nucleus divides first, and then the cytoplasm divides.

Plants, animals and most fungi are multicellular. They are made up of many cells and these cells are specialised. This means that that they contain different types of cells, each suited to a particular job. In humans, for example, red blood cells are very different from muscle cells and sperm cells. The cells lining the leaves of plants have a different shape from those found in the veins of leaves. Each type of cell has a particular structure that makes it well suited to its particular job. This would be similar to a large high school hiring a person with good secretarial skills to run the office, a trained chef to prepare food for the canteen and a teacher with a Science degree to teach Science.

An amoeba dividing by binary fission



INVESTIGATION 2.6

Observing yeast cells

AIM: To observe the process of budding in yeast

Yeast is used to make bread and many alcoholic beverages, including beer and wine. It is a unicellular organism that reproduces by budding. A small bud forms on the parent cell; the bud gradually becomes larger and eventually splits off.

You will need:

yeast culture
microscope slide and coverslip
microscope
dropper

- Use the dropper to draw up a sample of the yeast culture, including some of the brown scum. Place a drop of the yeast culture on the microscope slide. Cover with a coverslip.
- Observe the yeast, first under low power and then under ×400 magnification. Try to find cells budding.
- Draw diagrams of single yeast cells and budding yeast cells.

Discussion

1. Describe the appearance of the yeast cells.
2. Yeast cells convert certain sugars into alcohol and carbon dioxide gas. Bread dough contains sugars that yeast can convert to alcohol and carbon dioxide.
   (a) Adding yeast to bread dough causes it to rise after; the dough gradually expands and has bubbles in it. Explain why.
   (b) After yeast has been added to dough, it needs to be left undisturbed in a warm spot so it can rise. Explain why bread does not rise if you put it in a really hot oven straight after adding the yeast.
   (c) Explain why bread does not taste of alcohol (*Hint:* Alcohol evaporates at a temperature of about 80 °C.

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. **Distinguish** between unicellular and multicellular organisms.
2. **Identify** a feature that sets protists apart from other unicellular organisms.
3. List three protists.
4. **Outline** how unicellular organisms reproduce.
5. The cells of multicellular organisms are specialised. **Explain** what this means.

Think

6. A particular type of bacterium divides every 20 minutes.
   (a) Copy and complete the table at right.
   (b) Present the information above in the form of a line graph. Time should be on the horizontal axis and the number of bacteria on the vertical axis.
   (c) **Predict** the number of bacteria after 260 minutes.
   (d) Use your graph to estimate the number of bacteria after 90 minutes.
   (e) The population of bacteria will not continue to multiply at this rate. Suggest some reasons why the bacteria population might remain steady or decrease rather than continue to rise.
7. Use the **Binary fission** weblinks in the Resources tab to watch videos of unicellular organisms dividing and describe the process.

Time (minutes)	Number of bacteria
0	1
20	2
40	4
60	
80	
100	
120	
140	
160	
180	
200	

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Explore more with this weblink: Binary fission 1
Explore more with this weblink: Binary fission 2

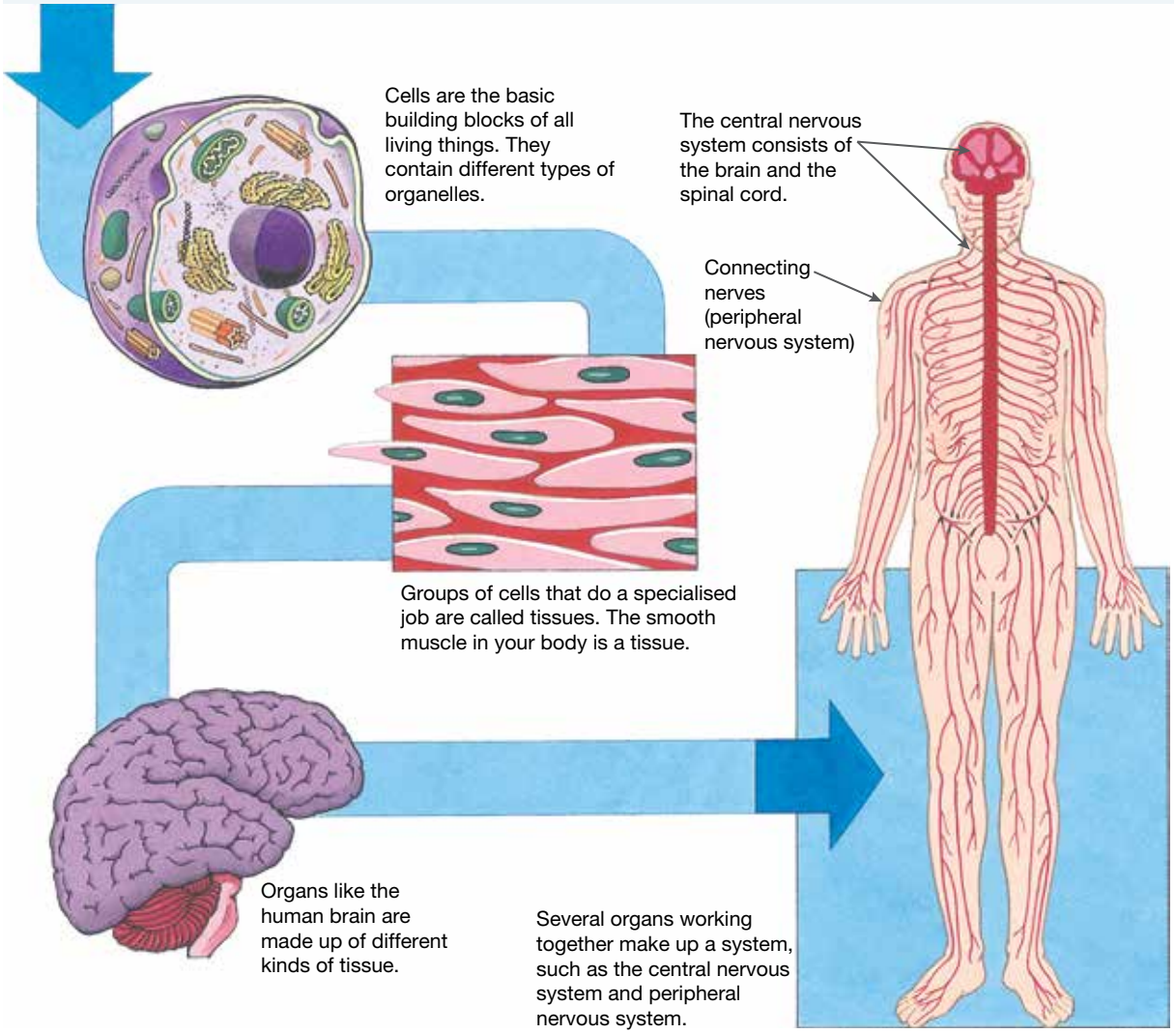
2.8 Cells getting organised

2.8.1 Levels of organisation

Complex organisms such as humans are made up of many different types of cells, each with a special job to do. But these cells do not function independently; they are organised into tissues, organs and systems so that they can work efficiently together.

Groups of similar cells that carry out a particular job make up **tissues**. The walls of the intestine contain smooth muscle tissue, which consists of a type of muscle cell. The heart is made up of cardiac muscle tissue, fat and connective tissue. Different types of tissues form **organs**. The heart, brain, lungs, liver and eye are all organs. Organs, in turn, are organised into **systems**. The kidneys, ureters and urethra are all part of the excretory system. The ovaries, fallopian tube and uterus are organs of the reproductive system. Each body system has a particular role to play in keeping an organism functioning. The table on following page shows the functions of some of the systems of the human body.

The building blocks of life



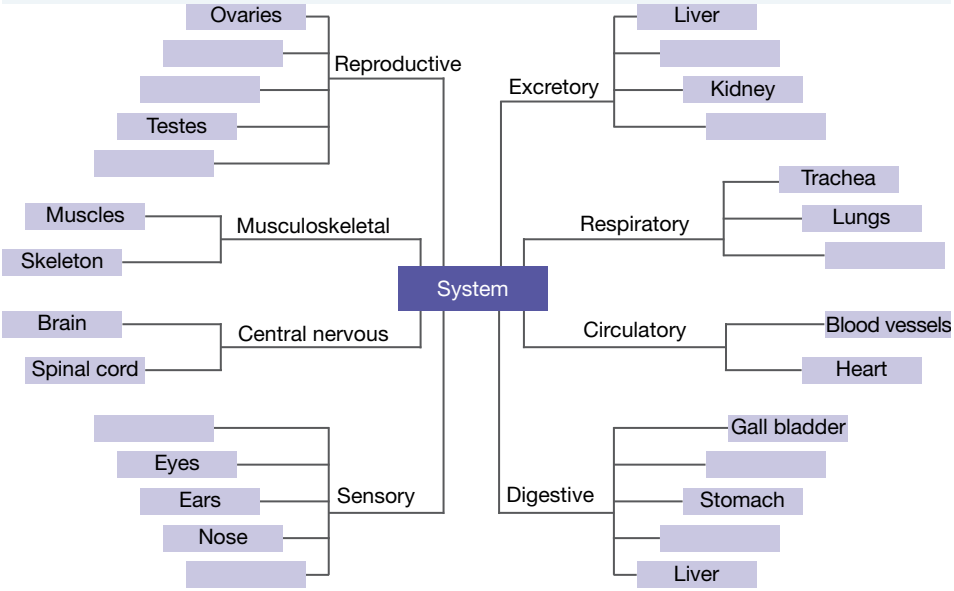
Some systems of the human body

System	Function
Digestive system	Breaks down the food we eat and moves nutrient particles into the bloodstream
Respiratory system	Moves air in and out of the lungs, takes oxygen from the air into the bloodstream and removes carbon dioxide from the blood
Excretory system	Filters out and removes some of the waste products from the bloodstream
Reproductive system	Is involved with making babies
Nervous system	Carries and processes messages from one part of the body to another along nerves
Musculoskeletal system	Allows the body to move, and some bones also protect important organs

2.8.2 Team work

Body systems cannot function independently of each other. The digestive system breaks down food but it is the circulatory system that carries nutrient particles to all the parts of the body. The respiratory system gets air in and out of the body and into the bloodstream, and the circulatory system delivers oxygen to cells and takes carbon dioxide back to the lungs. Similarly, muscles cannot move bones unless they receive a message from the nervous system.

Can you think of some organs that could go in the empty bubbles in this mind map?



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. Which body system:
   (a) transports substances around the body
   (b) is different in males and females?
2. List five examples of organs.
3. **Distinguish** between a tissue and an organ.
4. **Outline** the function of the:
   (a) respiratory system (b) circulatory system (c) digestive system.
5. Write the following in order from smallest to biggest: organism, cell, system, organ, tissue.

Think

6. CPR (cardiopulmonary resuscitation) can be used until an ambulance arrives to keep alive a person whose heart has stopped beating.
   (a) CPR simulates the action of which two body systems?
   (b) A person whose heart has stopped beating would rapidly die without CPR, even if their other body systems were still functioning normally at the time their heart stopped. **Explain** why.
7. Use the **Body systems mind map** weblink in the Resources tab. Save the file to your computer and then complete the mind map by filling in the empty boxes and adding at least three more systems and organs for each of these systems.

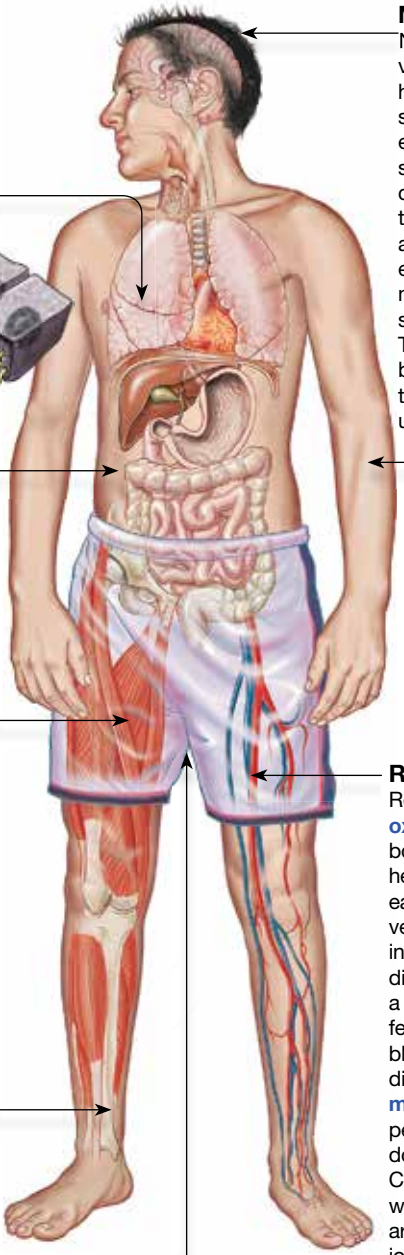
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Explore more with this weblink: Body systems mind map

2.9 Cells of all shapes and sizes

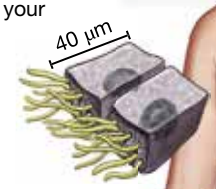
2.9.1 Body cells

The cells of multicellular organisms are specialised for the particular job they carry out, so they vary in their shape, size and structure.



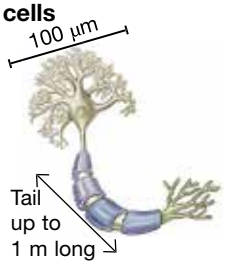
Lung epithelial cells

The cells that line your nose, windpipe and lungs are a type of lining cell. They have hair-like tips called **cilia**. These cells help protect you by stopping dust and fluid from getting down your windpipe. The cilia can also move these substances away from your lungs. You remove some of these unwanted substances whenever you sneeze, cough or blow your nose.



Motor nerve cells

Nerve cells are very long and have a star shape at one end. The long shape of nerve cells helps them detect and send electrical messages through the body at the speed of a Formula 1 racing car. There are nerve cells all over your body. They allow you to detect touch, smell, taste, sound, light and, unfortunately, pain.



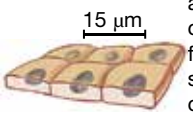


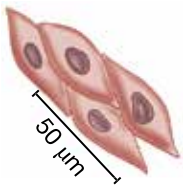
Adipose tissue cells

Some cells store fat. Fat stores a lot of energy for cells to use later. Round shapes are good for holding a lot of material in a small space. Fat cells are mostly found underneath your skin, especially in the chest, waist and buttocks.

Skin cells

Special cells line the outside surfaces of your body. These are the cells that form your skin. These cells have a flattened shape so they can better cover and protect your body.



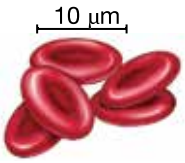


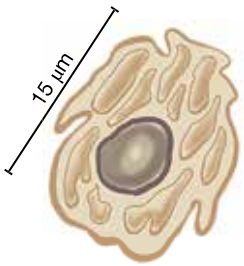
Muscle cells

Muscle cells are long and elastic. Long thin cells can slide further over each other to allow you to move. There are different types of muscle cells. The walls of your blood vessels and parts of your digestive system have smooth muscle cells. The muscles that are joined to your bones are called skeletal muscles. Skeletal muscles work in pairs — one muscle contracts (shortens) and pulls the bone in one direction while the other muscle relaxes.

Red blood cells

Red blood cells carry **oxygen** around the body. Their small size helps them move easily through blood vessels. The nucleus in a red blood cell dies soon after the cell is made. Without a nucleus, red blood cells live for only a few weeks. The body keeps making new blood cells to replace those that have died. Red blood cells are made in **bone marrow** at the rate of 17 million cells per minute! This is why most people can donate some of their blood to the Red Cross without harm. White blood cells, which are larger than red blood cells, are also made in the bone marrow. Their job is to rid the body of disease-causing organisms and foreign material.





Bone cells

Minerals such as calcium surround your bone cells. The minerals help make bone cells hard and strong. Bone cells need to be hard so that they can keep you upright.

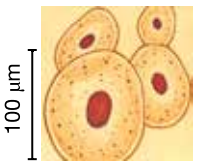
Sperm

Sperm cells have long tails that help them swim towards egg cells. Only males have sperm cells.



Egg cells

Egg cells are some of the largest cells in a human body. Their large round shape helps them store plenty of food. Only females have egg cells. When a sperm cell moves into an egg cell, the egg cell is **fertilised**.



2.9.2 Cell division

A human being starts out life as a single cell: a fertilised egg or zygote. The zygote divides into two cells, then into four, eight and so on. Initially all the cells look the same. They are not yet differentiated. As the cells continue to divide, they start to form distinct groups of cells. For example, by the time a baby is born, the cells of the retina of the baby's eye are very different from those that make up the bones of its

arm or the skin cells covering its body. The cells of the baby have become differentiated; that is, they are specialised. A question that has been extensively researched is why certain cells divide to produce one type of cell and other cells produce other types. How do the cells know what type of cell to become? One area of research is concerned with the location of each cell when the baby is just clump of similar looking cells: for example, whether a cell is towards the outside of the group or in the middle of the clump.

INVESTIGATION 2.7

Observing cells

AIM: To observe the features of different types of animal cells

You will need:

microscope

prepared slides of animal cells (e.g. human cheek cells, blood smear, nerve cells)

- Construct a table with the following column headings:
  – Type of cell – Description – Diagram.
- Observe each slide under the microscope and complete your table.
- If you have a digital eyepiece available, you may be able to take photos of the cells.

Discussion

1. Were all the cells you observed the same size?
2. Did all the cells have a nucleus?
3. Compare the diagrams of the cells with the appearance of the cells under the microscope.

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. Match each type of cell with its description.
2. **Outline** the function of the cilia of lung epithelial cells.
3. **Identify** two types of muscle cells.

Type of cell	Description
(a) Red blood cell	A Has a long tail that helps it swim
(b) Nerve cell	B Has a star-shaped cell body at one end with a very long tail-like structure attached
(c) Adipose tissue cell	C Is red in colour, very tiny and lacks a nucleus when mature
(d) Skin cell	D Is a blob-shaped cell that stores fat
(e) Sperm cell	E Is a flat cell that lines the outside surface of the body

4. **Compare** each of the following pairs of cells.
   (a) Red blood cells and bone cells
   (b) Egg cells and sperm cells
   (c) Epithelial cells and skin cells

Think

5. The structure of a cell (its shape and features) relates to its function. **Explain** this statement using three examples from the diagram on page 74.
6. Suggest why mature red blood cells are very small and lack a nucleus.
7. In *Investigation 2.7*, we used prepared slides to view blood cells. Many years ago it was common practice in schools for students to observe a drop of their own blood under the microscope. Suggest why it is no longer considered acceptable for students to prepare a slide of fresh human blood.

Data processing

8. (a) **Construct** a table with the following column headings: 'Type of cell', 'Function', 'Size', 'Shape'. Enter the relevant information in the table for each type of cell shown in the table on page 75.
   (b) **Construct** a column graph showing the size of each type of cell listed in your table.
9. Use the **Electron micrographs of human cells** weblink in the Resources tab to view pictures of cells produced with an electron microscope.
10. Use the **Cell jobs** interactivity to match cell types to their roles.

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Explore more with this weblink: Electron micrographs of human cells

Try out this interactivity: Cell jobs (int-0206)

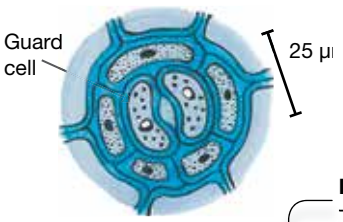
2.10 Focus on plants

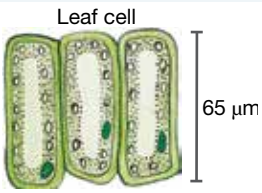
2.10.1 Plant cells

Plants are made up of different types of cells, each suited to a particular function.

Some of the types of cells found in plants

Guard cells
Guard cells are kidney-shaped cells found on the surface of leaves. They can change shape to either open or close the small hole between them. The small holes, called **stomata** (or stomates), allow substances such as carbon dioxide to enter the leaf. They also let water out of the leaf. Most plants open their stomata at night; they close their stomata during the day (when it is hotter) to conserve water.

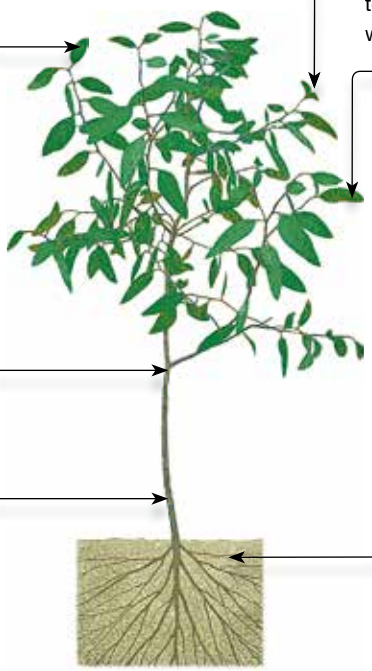




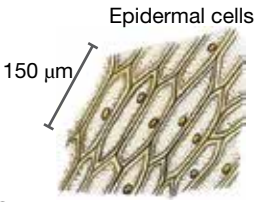
Leaf cells (palisade cells)
The main function of leaf palisade cells is to photosynthesise, so they are packed with chloroplasts and are usually green.

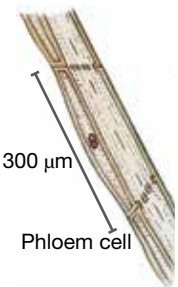


Xylem cells
Xylem cells form xylem tubes, which carry water and dissolved minerals from the roots to all parts of the plant. They are made up of dead xylem cells joined end to end. When xylem cells die, the cell walls at each end of the cells dissolve, forming a long straw-like tube. They have thick cell walls with lots of cellulose to make the xylem tubes strong.



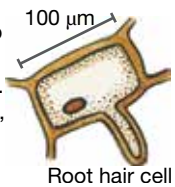
Epidermal cells
Epidermal cells are found on the outside of the plant. They form an outer skin for the plant and protect the cells underneath. This explains why they need a flat shape and why they interlock like tiles. Epidermal cells do not usually photosynthesise so they lack chloroplasts. Light needs to pass through them, and they are usually transparent. The cells in the diagram below are onion epidermal cells.





Phloem cells
Like xylem cells, phloem cells form tubes. The tubes formed by phloem cells carry the food made in the leaves to all parts of the plant. Phloem cells do not need to die to do this job. The ends of phloem cells have holes and look like sieves.

Root hair cells
Root hair cells absorb water and dissolved minerals from the soil. They have small hairs, called root hairs, on their surface. This increases the surface area of the root cells so that they can soak up water more quickly.



INVESTIGATION 2.8

Plant cells in view

AIM: To observe the features of different types of plant cells

You will need:
light microscope
prepared plant slides: leaf epidermal cells, root hair cells, stomata/guard cells

- Construct a table like the one below, making it large enough for all of your results.
- Use a microscope to observe the prepared slides, recording your observations in the table as you make them.

Discussion

1. Which features did the plant cells have in common?
2. In what ways did the plant cells differ from each other?
3. Why are there some features that all cells possess?
4. Find out the functions of the different types of cells examined.
5. Suggest how the shape or size of the cells may assist the cell in doing its job.
6. Suggest reasons for some of the differences observed between the cells.

Source of specimen	Type of specimen	Sketch of specimen	Description of specimen
Plant	Leaf epidermal cells	[Allow as much space as you can; draw only two or three cells, in pencil, and include magnification and estimated size.]	[Describe in words what the specimen looked like.]

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. Match each type of cell with its function.

Type of cell	Function
(a) Root hair cell	A Changes shape to open and close pores in the leaf
(b) Xylem cell	B Increases surface area for efficient absorption of water and minerals
(c) Guard cell	C Carries water and minerals up the plant

2. **Deduce** why the epidermal cells in leaves have a flattened shape.
3. **Outline** how xylem cells form into long tubes.
4. **Recall** which cells make up the tubes that transport food in the leaves down through the stem.

Think and reason

5. **Explain** whether you would expect to find chloroplasts in roots.
6. (a) Copy and complete the table below using the information in the diagram on the previous page.

Type of cell	Size (μm)
Guard cell	Length =
Phloem cell	Length =
Palisade cell	Length =
Onion epidermal cell	Length =
Xylem cell	Width =

(b) **Calculate** the average size of the cells listed in the table in part (a).
(c) **Construct** a column graph of the data in part (a), showing cell type on the horizontal axis and cell size on the vertical axis.

7. **Deduce** how guard cells got their name.
8. Guard cells and stomata usually occur only on the lower part of the leaf, away from direct sunlight. **Explain** why.
9. Why are all plant cells not the same?

Create

10. **Construct** a working model of a pair of guard cells, using balloons.

2.11 Review

2.11.1 Study checklist

The microscope

- **recall** the parts of a school microscope and state their functions **2.2**
- **explain** the difference between a light and an electron microscope and the advantages of each **2.3**
- prepare a specimen for viewing under a school microscope **2.2, 2.5**
- **explain** why stains are used when preparing microscope slides **2.5**
- use a microscope to obtain a focused image of a specimen **2.2, 2.5, 2.7**
- **explain** why the invention of the microscope had a significant impact on biology **2.4**
- **describe** van Leeuwenhoek's contribution to the field of microbiology **2.4**
- **interpret** a timeline such as the one on pages 56–57 **2.4**

Looking at cells

- **recall** that a micrometre is 1/1 000 000th of a metre, and convert measurements from micrometres into millimetres and metres **2.2**
- draw labelled diagrams of an animal cell and a plant cell as viewed under a light microscope **2.5, 2.7**
- **describe** the functions of the following cell parts: nucleus, cell membrane, cell wall, chloroplast, cytoplasm, mitochondrion **2.5**
- draw labelled diagrams of a specimen viewed under the microscope **2.2, 2.5, 2.7**

Unicellular and multicellular organisms

- **explain** the difference between unicellular and multicellular organisms, and list examples of each **2.8**
- **explain** how things move in and out of cells **2.6**
- **explain** how unicellular organisms reproduce **2.8**
- **recall** examples of different types of cells found in animals, such as humans, and their functions **2.7**
- **explain** how the structure of a cell is related to its function, using examples **2.7**
- **explain** the meaning of the terms 'tissue', 'organ' and 'system', and give examples of each in both plants and animals **2.7**

Individual pathways

ACTIVITY 2.1
Revising cells
doc-10533

ACTIVITY 2.2
Investigating cells
doc-10534

ACTIVITY 2.3
Investigating cells further
doc-10535

learnon ONLINE ONLY

FOCUS ACTIVITY

online only

Create a video or photostory demonstrating one of the following procedures.

- How to prepare a specimen (e.g. a piece of onion skin) for viewing under the microscope
- How to focus a microscope
- How to draw a specimen viewed under a microscope
- How to take a photo of a specimen with a digital eyepiece

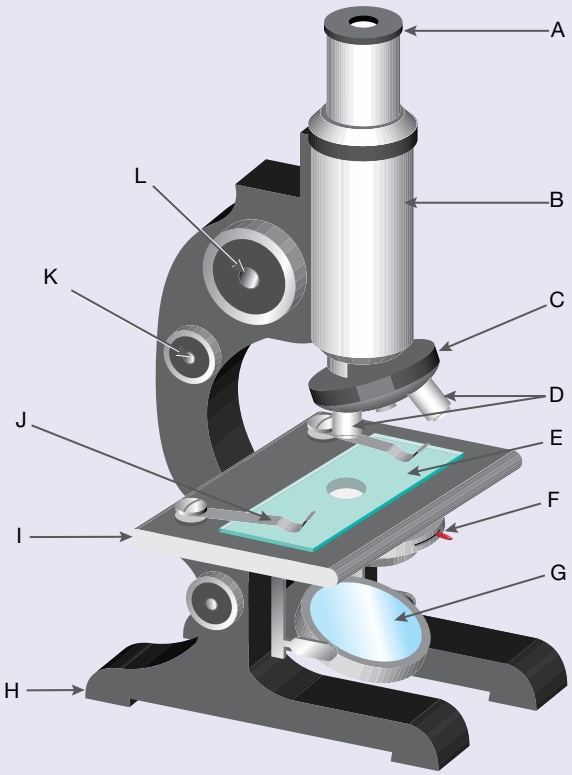
Access more details about focus activities for this chapter in the Resources tab (doc-10532).

2.11 Review 1: Looking back

assessON

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) **Identify** the labelled parts in the diagram below.



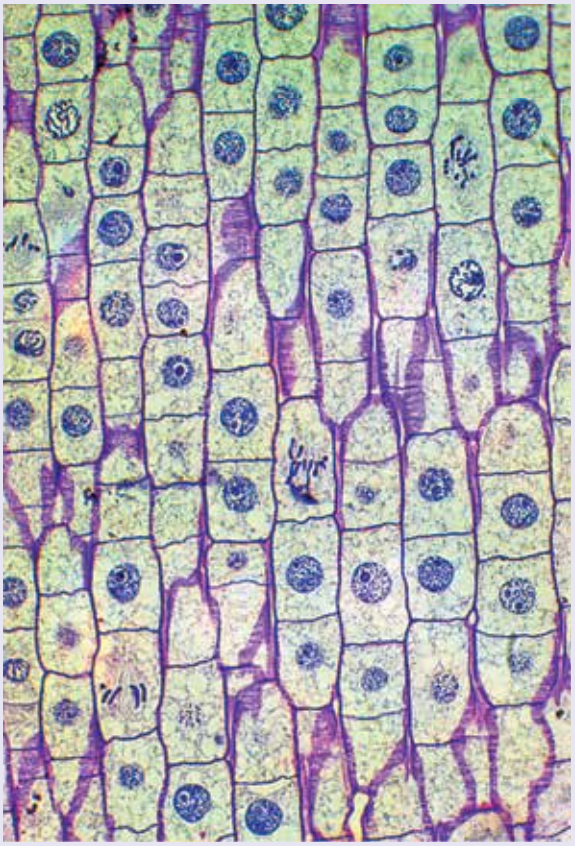
   (b) **Outline** the functions of parts A, C, D, G, I, J, K and L. Present your answers in a table.
2. Your teacher has asked you to examine a sample of pond water under the microscope.
   (a) Draw a labelled diagram of the microscope slide ready for viewing under the microscope.
   (b) The school microscope has an ocular (eyepiece) lens that provides ×10 magnification. What is the total magnification when the ×40 objective lens is used?
3. **Deduce** which of the following types of microscopes were used to take the photos shown at the top of the next page.
   - Scanning electron microscope
   - Light microscope
   - Transmission electron microscope

   Explain your answers.

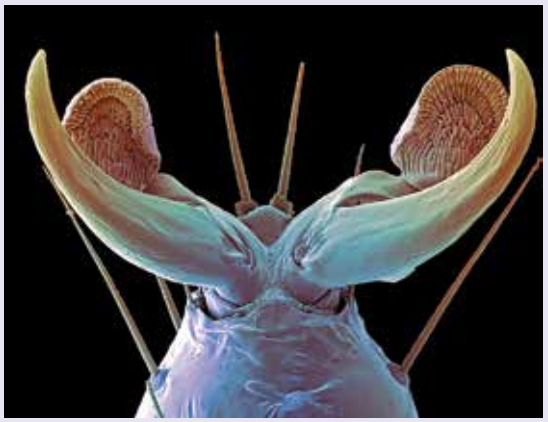
(a)



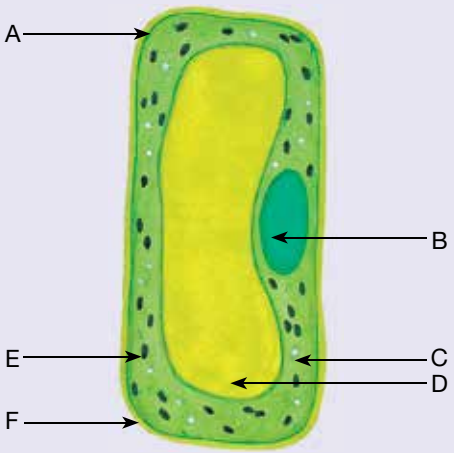
(b)



(c)



4. Outline the major contribution that each of the following scientists made to the field of microbiology.
   - Anton van Leeuwenhoek
   - Robert Hooke
   - Robert Brown
   - Ernst Ruska
5. A diagram of a cell is shown below.



   (a) Is the cell an animal or a plant cell? **Justify** your answer.
   (b) Name the parts labelled A–F and tabulate the function of each part.
6. Unscramble the letters using the clues provided
   (a) SEUNCLU: Control centre of the cell
   (b) ERAMMBNE: Surrounds the cell
   (c) OCVAUEL: Contains cell sap
   (d) CATOPLMYS: Part of the cell between the cell membrane and the nucleus

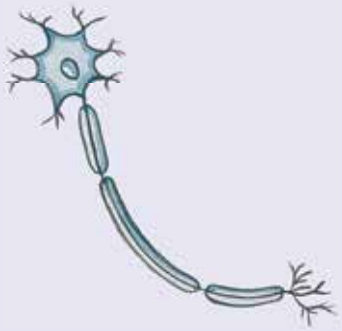
7. Match the following cell names to the diagrams below.
   Euglena
   Paramecium
   onion epidermal cell
   nerve cell
   sperm cell
   bacterium

(a)


(b)

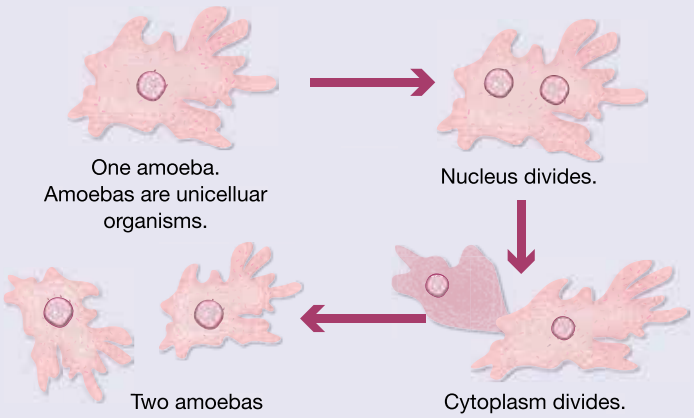

(c)


(d)


(f)


(e)


8. **Identify** two organs that belong to each of the following systems.
   (a) Digestive system
   (b) Respiratory system
9. Name the process shown in the diagram below.



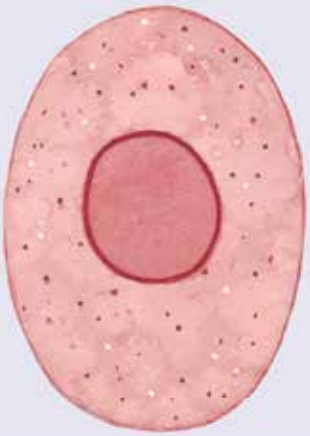
10. Read the following story.
    Charlotte has a small pond in her backyard. The weather has been warm and sunny and the pond has turned green. Charlotte suspects that algae may be growing in the water.
    (a) Describe how Charlotte could use a microscope to find out if there are algae growing in the water. Write your answer as a procedure.
    (b) When Charlotte looked at a sample of pond water under the microscope, she saw various organisms. A sketch of one of the organisms is shown below. Is the organism unicellular or multicellular? **Justify** your answer.



11. Choose any two types of plant cells and **outline** how the structures of these cells relate to their functions.

Test yourself

1. Refer to the diagram of the microscope on page 79. Which of the following parts magnify the image?
   (A) A and G
   (B) A and D
   (C) D only
   (D) G only **(1 mark)**
2. What is the function of the cell membrane?
   (A) It controls the cell.
   (B) It gives the cell its shape and supports the cell.
   (C) It regulates what can enter and leave the cell.
   (D) It is where respiration occurs. **(1 mark)**
3. A diagram of a cell is shown at right.
   Which of the following statements is true of this cell?
   (A) It is an animal cell because it has a nucleus.
   (B) It is a plant cell because it has a cell membrane.
   (C) It is a plant cell because it has a large vacuole.
   (D) It is an animal cell because it lacks chloroplasts. **(1 mark)**



4. **Identify** which of the following statements is true.
   (A) Tissues are made of different types of organs.
   (B) A system is made of organs working together.
   (C) The skin is made up of one type of tissue.
   (D) Blood is an example of lining tissue. **(1 mark)**
5. In the human body there are many different kinds of cells.
   (a) Use at least two examples to **explain** why there are cells of different shapes and sizes. **(3 marks)**
   (b) Draw a labelled diagram of a type of cell found in the human body. **(2 marks)**
   (c) **Explain** why substances need to move in and out of cells. **(2 marks)**

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Complete this digital doc: Worksheet 2.5: Cells puzzles (doc-12358)

Complete this digital doc: Worksheet 2.6: Cells summary (doc-12359)

TOPIC 3
States of matter

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?

Most substances on Earth can be classified as being solids, liquids or gases. By comparing the characteristics of substances, a great deal of information can be deduced about their internal structure and future behaviour.

LEARNING SEQUENCE

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Strange conical, doughnut-shaped or even egg-shaped clouds (called Prandtl–Glauert condensation clouds) can suddenly appear around jets like this FA18 Hornet. The movement of the fast jet slices through the air particles producing areas of very low pressure. This causes the water vapour in the air to condense into tiny droplets of liquid water where the air pressure is lowest. The shape of the condensation clouds produced depends upon the humidity, the profile of the aircraft and its speed.



Ranking substances

1. In small groups, rank the following substances in order from most solid-like to most liquid-like to most gas-like.

a brick	steam
jelly	plasticine
sugar	tomato sauce
Vegemite®	air
orange cordial	green slime

2. Compare your rankings with those of other groups. Comment on any differences between the rankings.
3. Which substances were most difficult to classify as solid, liquid or gas? Explain why they were difficult to classify.
4. Draw a three-column table, like the one below, and separate the substances into three categories — solid, liquid or gas.

Solid	Liquid	Gas

5. Different liquids pour or flow in different ways. Test this by pouring honey, shampoo, cooking oil and water from one container to another. Time how long they take to pour. Make sure it is a fair test. Record the results in a table and write a conclusion based on your observations and results.

Green slime — is it solid or liquid? How do you know?



HOW ABOUT THAT!

While we generally refer to only the three states of matter that are most usually encountered naturally on Earth — solid, liquid and gas — scientists have actually defined other states that matter in the universe may be found in. These include plasma, superfluid, super-solid, degenerate matter, strange matter and Bose–Einstein condensate (BEC).

Bathroom science

1. Why does the mirror fog up in the bathroom after someone has had a hot shower?
2. On really hot days, you may have a cold shower to cool down. Does the bathroom mirror fog up when you do this?
3. Some showers have shower curtains rather than glass shower screens. When people have warm showers, the curtain tends to move in towards the person in the shower and stick to them — it's almost as if the shower curtain is chasing them! Give possible explanations for why this happens.
4. When you have a hot shower, the bathroom fills with steam. Is this steam a gas or a liquid or both? Explain your reasoning.
5. How hot does water have to be before it can burn you?
6. Does steam always rise?
7. Are water vapour and steam the same thing?

What is steam — a gas, a liquid, or both?



3.2 What's the matter?

3.2.1 Solids, liquids and gases

We use the term **matter** to describe anything that has mass or takes up space. This means that everything in the universe that isn't empty space is made up of matter. Matter, in turn, is made up of particles. The way in which a particular substance behaves and how it appears depends upon the characteristics of the particles of which it is made, including the size and composition of these particles, the distances between them, the speed of their movement and how they interact with other particles.

Matter is found in a variety of forms, which we refer to as **states of matter**. While scientists have identified a number of different states of matter, the vast majority of substances that we encounter are **solids**, **liquids** or **gases**.

We can categorise substances as being solids, liquids or gases by looking at their physical appearance and behaviour.

INVESTIGATION 3.1

Comparing solids, liquids and gases

AIM: To compare some features of solids, liquids and gases

You will need:

ice cube
spatula
beaker of water
plastic syringe
balloon

- Pick up an ice cube and place it on the bench. Using a spatula, try to squash it or compress it to make it smaller.
- Take the beaker of water and draw up a small amount into the syringe. Place your finger over the opening at the end of the syringe and press down on the plunger.
- Partially inflate a balloon with air and hold the opening tightly closed. Try to squeeze the balloon.
- Release your hold on the opening of the balloon.

Discussion

1. Copy the table below and use your observations to complete it.
2. Where did the air in the balloon go when you released the opening?

Properties of solids, liquids and gases

Substance	State of substance	Can the shape be changed easily?	Does it take up space?	Can it be compressed?
Ice	Solid			
Water	Liquid			
Air	Gas			

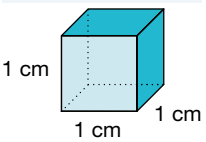
3.2.2 Matter characteristics

In order to determine whether a substance is a solid, a liquid or a gas (or something else entirely), we need to assess the way in which the matter in it is distributed and how it behaves.

The amount of matter in an object is referred to as its **mass**. Mass is generally measured in either grams (g) or kilograms (kg). Instruments such as electronic scales, triple-beam balances, spring scales and even bathroom scales can all be used to determine the mass of an object. In general, the mass of an object remains the same regardless of changes to its location, shape or volume.

The amount of space taken up by a solid, liquid or gas is called its **volume**. The volume of a solid (and, occasionally, a fluid) is measured in cubic metres (m^3) or cubic centimetres (cm^3).

This cube has a volume of 1 cm^3 and can hold 1 mL of a fluid.



The volume of a fluid is measured in millilitres (mL) or in litres (L). The term **fluid** is used to describe any substance that flows, so liquids and gases are both classified as fluids. Sometimes you will see fluid volumes given in cm^3 rather than mL. To convert between the two measurements remember that:

$$1 \text{ mL} = 1 \text{ cm}^3$$
$$1 \text{ L} = 1000 \text{ cm}^3$$
$$1000 \text{ L} = 1 \text{ m}^3$$

A measuring cylinder is most commonly used to determine the volume of a liquid. The volumes of solids that have regular shapes, such as cubes, spheres or prisms, can be calculated using geometry after you have measured their dimensions with a ruler. However, as you will see in *Investigation 3.2*, the volumes of solids that have irregular shapes are easiest to find by looking at how much water they displace — a principle first used by the Greek mathematician Archimedes in the third century BCE.

In some situations, the volume of a substance can be made smaller by forcing the particles in the substance closer together. Substances that require little effort to squeeze their particles together are said to be **compressible**, while those that require a large amount of force to squeeze the particles together are said to be **incompressible**.

INVESTIGATION 3.2

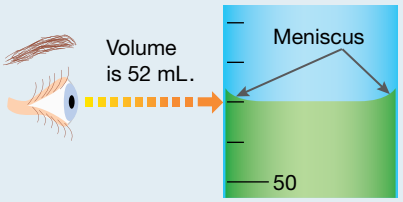
Measuring the volume of an irregular shaped solid

AIM: To measure the volume of an irregular solid

You will need:
100 mL beaker
100 mL measuring cylinder
stone or pebble that will fit into the measuring cylinder

- Half-fill (approximately) a 100 mL beaker with water.
- Carefully pour the water into the measuring cylinder.
- Read and record the volume of water in the measuring cylinder using the technique shown in the diagram below.
- Carefully place the pebble into the measuring cylinder. Take care not to spill any water out of the measuring cylinder.
- Read and record the new volume.

Reading the volume of a liquid in a measuring cylinder. The curved upper surface is called the meniscus. Your eye should be level with the flat part in the centre of the meniscus.



Discussion

1. What was the volume of the pebble in millilitres (mL)?
2. What was the volume of the pebble in cubic centimetres (cm^3)?
3. Suggest another method of measuring the volume of a solid that has an irregular shape.
4. You are designing a new type of armchair. It needs to be comfortable and capable of fitting in different positions or spaces around the room. Describe the properties you would want in the chair. Would you need to develop a new material to match these properties? If so, explain whether it would be a solid or a liquid, or perhaps a combination of states.

3.2.3 The states of matter

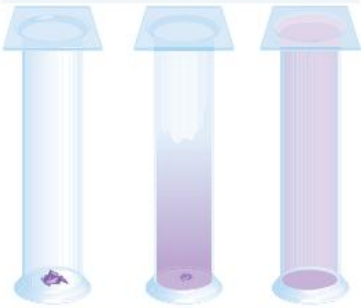
Solids are substances that keep the same size and shape regardless of the shape of container in which they are placed. They are extremely difficult to compress so their volume is considered to be unchanging. Metals, glass and rock are all examples of solids.

Liquids, such as water, oil and honey, are substances that keep the same volume but have no fixed shape. Instead, they take on the shape of the container in which they are placed. If poured into a jar, they take on the shape of the jar. When poured into a measuring cylinder, they take on the cylinder's shape. If poured onto a flat benchtop, they flatten and spread out over the surface.

Gases, like liquids, also take on the shape of their container. However, unlike solids and liquids, they are compressible so their volume can be made larger or smaller. If you blow air into a balloon, for example, you can squeeze the balloon to make it smaller, decreasing the volume of the air inside.

Gases spread out and do not stay inside a container unless it has a lid. The gas particles move around, taking up all of the available space. This movement is called **diffusion**. In the illustration below, iodine gas is being formed and is spreading, or diffusing, throughout the gas jar.

The purple iodine gas diffuses, taking up all of the available space. What would happen to the gas if the lid is removed?



3.2 Exercise: Understanding and inquiring

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** as many as you can remember of the solids, liquids and gases you came in contact with before leaving for school today. Organise them into a table under the headings 'Solids', 'Liquids' and 'Gases', or into a cluster, mind or concept map.
2. (a) **Recall** three properties that most solids have in common.
   (b) Would liquids have the same three properties? If not, **describe** the differences that might be expected.
3. **Compare** the properties of gases and liquids.
4. **Recall** which unit is used for measuring small volumes such as that of liquid medicines. **Explain** how you could measure such a volume.

Think

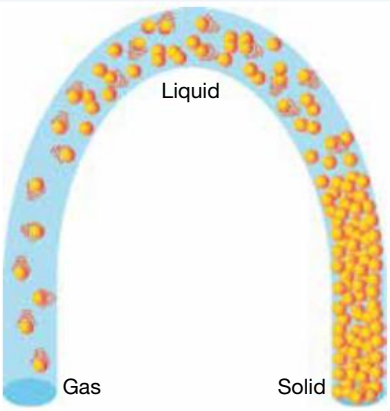
5. Both steel and chalk are solids. **Describe** the properties of steel that make it more useful than chalk for building bridges.
6. Are plasticine and playdough solids or liquids? **Explain** your answer fully.
7. **Define** the term 'diffusion'. Give two examples of this occurring around your house.
8. Is it possible for a solid to behave like a fluid? **Explain** your answer.
9. At the petrol station, the safety sign asks for the car engine to be switched off before you fill the petrol tank. **Explain** why this is necessary.

IMAGINE

10. You are designing a new type of armchair. It needs to be comfortable and capable of fitting in different positions or spaces around the room. **Describe** the properties you would want in the chair. Would you need to develop a new material to match these properties? If so, **explain** whether it would be a solid or a liquid, or perhaps a combination of states.

3.3 The particle model

A particle model for different states



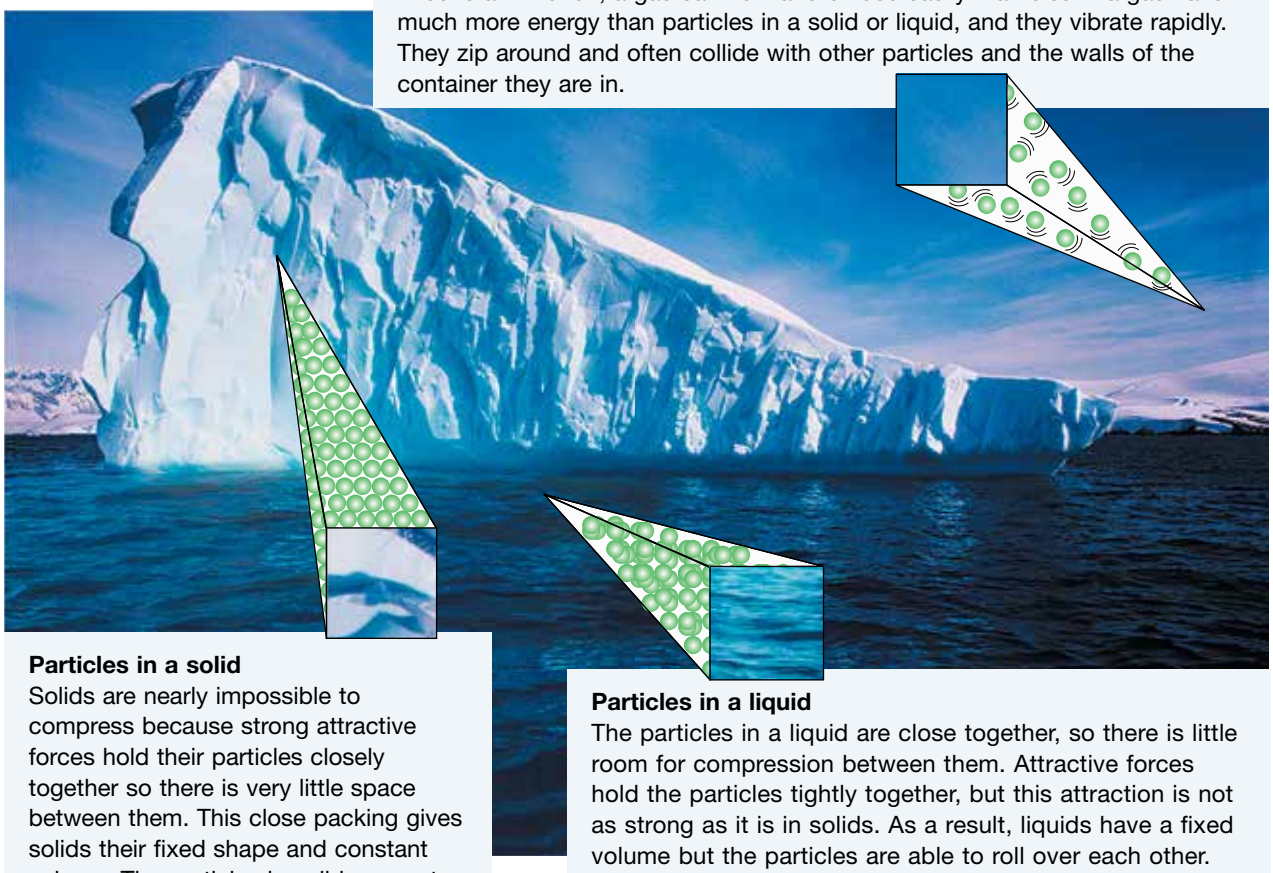
3.3.1 Particles in action

How do you explain why ice has properties that are different from those of water or steam? Scientists use a model to explain the different properties of solids, liquids and gases. This model is called the **particle model**.

According to the particle model:

- all substances are made up of tiny particles
- the particles are attracted towards surrounding particles
- the particles are always moving
- the hotter the substance is, the faster the particles move.

Particles in a gas
The particles in a gas are only weakly attracted to each other. As a result, gases have no fixed shape or volume. The distance between gas particles is very large. These large spaces allow gases to be easily compressed as there is plenty of room for particles to fit between each other. As gas particles are in constant motion, a gas can flow and diffuse easily. Particles in a gas have much more energy than particles in a solid or liquid, and they vibrate rapidly. They zip around and often collide with other particles and the walls of the container they are in.



Particles in a solid
Solids are nearly impossible to compress because strong attractive forces hold their particles closely together so there is very little space between them. This close packing gives solids their fixed shape and constant volume. The particles in solids cannot move freely but they vibrate in fixed positions. This means that solids are unable to flow like fluids.

Particles in a liquid
The particles in a liquid are close together, so there is little room for compression between them. Attractive forces hold the particles tightly together, but this attraction is not as strong as it is in solids. As a result, liquids have a fixed volume but the particles are able to roll over each other. This rolling allows liquids to flow until the walls of their container interrupt their spread. The particles in a liquid are more energetic and vibrate faster than those in a solid but less so than the particles in a gas.

HOW ABOUT THAT!

Even though water has been found in the form of ice on many planets, the Earth is the only one that we know of where water can be found naturally occurring in all three states of matter all year round. Solid ice can be seen in glaciers and at the poles. Liquid water fills our oceans and streams and even falls from the sky, while water vapour (which is invisible) can be found in our atmosphere.

INVESTIGATION 3.3

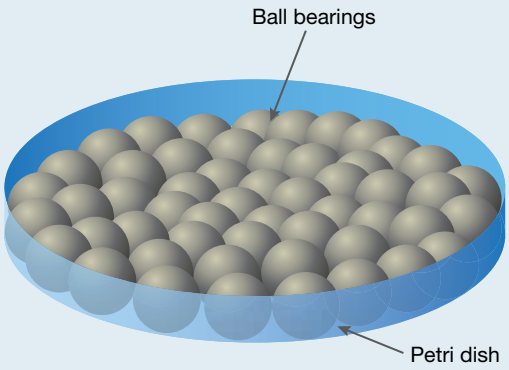
Modelling particles of matter

AIM: To demonstrate the particle model

You will need:
ball bearings
plastic Petri dish with lid

- Pour as many ball bearings as possible in a single layer in the Petri dish so that they completely cover the bottom, as shown below. Put the lid on and keep it in place as you shake the Petri dish from side to side.

- Remove about a quarter of the ball bearings from the Petri dish. Put the lid back on and now observe what happens when you shake the Petri dish from side to side.
- Remove most of the ball bearings, leaving only a few behind in the Petri dish. Replace the lid and shake the dish.



Discussion

1. Describe the amount of movement of the particles (ball bearings) in the dish when the bottom is covered. What state of matter do you think this represents?
2. What state of matter do you think is represented when a quarter of the particles are removed?
3. What state of matter do you think is represented when most of the particles are removed?
4. In which of the three arrangements did the particles have
   (a) the largest spaces between them
   (b) the greatest freedom of movement?
5. Compare the movement of the particles in the liquid arrangement with that in the solid arrangement.
6. Consider the amount of space that there was between particles in the solid arrangement and those in the gas arrangement. When we compress a substance, we move the particles in the substance closer together. Explain why it is easier to compress a gas than a solid.

3.3.2 Using the particle model

The main reason that the particle model is so helpful is that it allows us to better visualise how the particles of matter behave in different circumstances. It also enables us to predict real-world behaviour. In reality, the particles of matter are much too small to observe directly as they interact with each other and with energy; in most cases, this model is enough like reality for it to be useful.

However, it should be realised that a model is a simplification of a much more complex reality.

An exception to the model

According to the particle model, the spaces between the particles in a liquid get smaller and smaller as the liquid is cooled, and they are closest together once it has become a solid. However, water is one of the few substances that do not behave exactly as the particle model predicts.

While the temperature of water is cooled from 100 °C to 4 °C, the particles behave as expected, with the spaces between them growing smaller. At lower temperatures, however, something strange happens. As water temperature drops below 4 °C, the spaces between the particles start to get larger again. By the time water freezes at 0 °C, the particles are further apart than they were at 4 °C! In general, the volume taken up by water particles increases by nearly 10 per cent when it becomes ice; you may have noticed this if you have ever put a full bottle of water in the freezer!

Oops! The reason why you shouldn't put a bottle full of water in the freezer



3.3 Exercise: Understanding and inquiring

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Remember

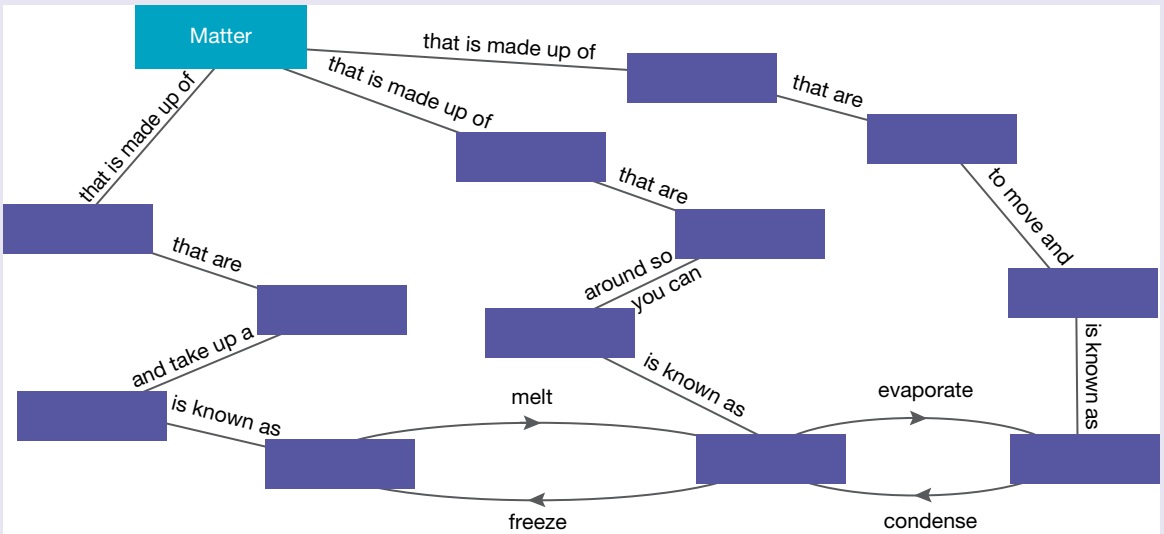
1. **Recall** the basis of the particle model.
2. **Define** the term 'diffusion'.
3. Give an everyday example of diffusion at work.
4. Copy and complete the table below.

Property	Solid	Liquid	Gas
Particle arrangement			
Force of attraction between particles			
Movement of particles			
Ability to diffuse			

5. The following statements are incorrect. Rewrite them correctly.
   (a) To change a liquid to a solid you have to heat it.
   (b) Heating a liquid might make the particles stick closer together.
   (c) Solids do not have a definite shape because the particles are free to move around.
   (d) You can compress a gas because its particles are close together.

Think

6. **Explain** why solids have a fixed shape.
7. **Explain** why gases can be compressed.
8. **Explain** why gases fill their containers.
9. When you pour cordial into water, the two liquids slowly mix together even though you don't stir them. **Explain** how this happens.
10. **Describe** what happens to the particles in a gas when it becomes a liquid. **Recall** what this change of state is called.



11. Use the particle model to **explain** why:
   (a) perfume can be smelled from a few metres away
   (b) steam can be compressed while ice cannot
   (c) an ice cube melts and changes shape when it is taken out of the freezer
   (d) water vapour takes up more space than the same amount of liquid
   (e) solids do not mix well, but gases and liquids mix easily in most cases.

12. **Explain** why wet clothes dry more quickly on a windy day than on a still day.
13. The concept map below represents some of our knowledge about the states of matter. This concept map is just one way of representing ideas about matter and how they are linked. However, all but one of the key terms in the ellipses are missing.
    Copy the concept map and complete it by writing in suitable keywords in the ellipses.
    Select the keywords from the list below. One keyword is used three times.

fill space	liquid	sliding
fixed shape	particles	solid
free	pour	vibrating
gas		

14. Use the **Phases of matter in containers** weblink in the Resources tab to watch how solids, liquids and gases behave differently within a container.

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Complete this digital doc: Worksheet 3.1: States of matter (doc-12360)
Watch this eLesson: Priestley and the Law of Conservation of Mass (eles-1767)
Explore more with this weblink: Phases of matter in containers

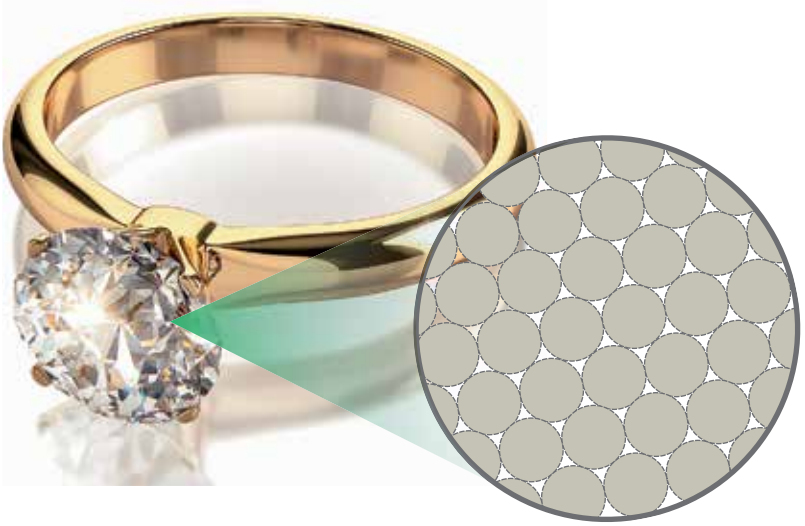
3.4 A solid performance

3.4.1 Types of solids

The particles in solids are held closely together by strong attractive forces with very little separation between the particles. The properties and appearance of a solid depend upon the types of particles of which it is made and the way in which these particles are arranged.

More than 90 per cent of solids are **crystalline solids**, which are made up of particles arranged in regular, repeated units. Metals, table salt, minerals, graphite and rubies are all made up of particles held tightly together by very strong bonds in regular patterns.

The particles that make up this diamond ring are packed closely together in a regular pattern.



Copper sulfate is a mineral that can be found naturally in regular crystal shapes.

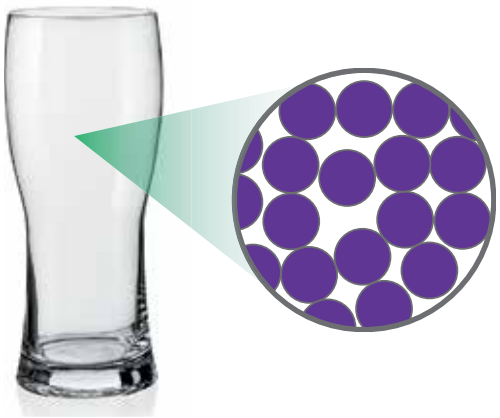


Graphite is sometimes used in artists' pencils. It is found naturally as a rock with many layers; this indicates that the particles are arranged in a regular pattern.



Other solids such as glass, amber and some plastics are made up of particles that are packed together with an irregular structure. These are called **amorphous solids**. The particles in amorphous solids are still held very tightly together by strong bonds, but they are arranged in a more random fashion than in crystalline solids.

Glass is an amorphous solid. Its particles are arranged in an irregular way, but they are still packed closely together.



3.4.2 Flexibility and strength

When we say that someone is flexible, we mean that they are able to move and bend their bodies easily into different, sometimes amazing, positions without suffering any ill effects, while someone who is strong can lift and carry large amounts of weight at one time. Solids can also be described in terms of flexibility and strength. These qualities are of special interest to engineers and designers who must select materials for specific jobs based on their structural characteristics. For example, iron is used for building bridges because it is very strong while a material such as cardboard could not be used.

INVESTIGATION 3.4

Testing strength and flexibility

AIM: To test the strength and flexibility of different materials

You will need:

wooden, metal and plastic rulers (all of the same length)
string
brass weight set (with a carrier and 50 g weights)
two chairs
safety glasses

Flexibility

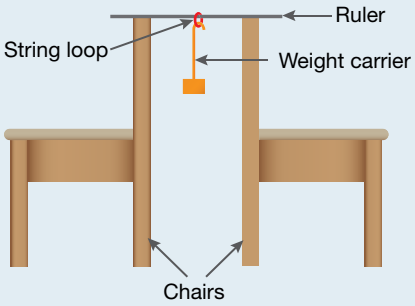
- Take a ruler and hold it by each end. Bend the ruler's ends towards each other, taking care not to bend the ruler so much that it snaps! Place the ruler on a flat surface and examine whether the ruler is still flat. Repeat for the other two rulers.

Strength

- Make a loop of string and knot it tightly so that it won't slip. Pass the wooden ruler through the loop and let the loop hang from the ruler at the halfway mark.

- Arrange two chairs back to back with a gap between them. Place the ruler between the chairs so that each end of the ruler is supported by one of the chair backs. Hang the weights carrier from the string loop and make sure that the loop is across the centre of the ruler.
- Add 50 g weights to the carrier one at a time and observe what happens to the ruler as the weight increases.
- Make a note of the maximum weight that the ruler is able to support without either snapping or bending beyond repair. (This is called the point of failure of the ruler.)
- Repeat for the other two rulers.

Setting up the strength test



Discussion

1. Which of the rulers was the most flexible?
2. Which ruler was able to take the most weight?
3. Which ruler was the first to reach the point of failure?
4. What happened to the rulers as the weight on them was increased?
5. Was the strongest material the least flexible? Explain.
6. Which of these materials would be the most suitable for building a bridge? Explain your answer.

A solid selection

Different solids are used for purposes that match their particular characteristics, such as strength, flexibility, cost, weight and hardness. The table below shows just a few.

Solid	Properties	Uses
Concrete	Hard, strong, long lasting	Paths, buildings, walls
PET (plastic)	Soft, flexible, strong, transparent	Drink bottles
Ceramics	Waterproof (if glazed), heatproof, strong, hard	Plant pots, kitchen tiles, roof tiles, heat tiles on space shuttle
Copper	Easily shaped and stretched, unreactive, excellent conductor of heat and electricity	Electrical wiring, pots and pans, pipes for plumbing
Aluminium	Strong, easily shaped and stretched, light, unreactive	Aircraft, bicycles, engines, drink cans
Diamond	Very hard, transparent, strong	Cutting tools, jewellery
Wood	Hard, strong, attractive, flammable	Building, furniture, fuel in freplaces

3.4 Exercise: Understanding and inquiring

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 crystalline solids and amorphous solids.
2. Give two examples of a crystalline solid.
3. What do we mean when we say that a material is flexible?
4. **Identify** the properties of aluminium that make it suitable for use in building aircraft.

Think

5. **Explain**, in terms of particles and bonds, why the concrete and steel in a skyscraper can bend.
6. Draw a diagram that shows the difference between the arrangements of particles in crystalline solids and amorphous solids.
7. For each material in group (a), select a matching property from group (b) and a use from group (c).
   (a) Marble; iron; gold; polystyrene
   (b) Easily shaped and attractive; light and soft; strong and hard; hard and attractive
   (c) Statues; jewellery; packaging; horseshoes

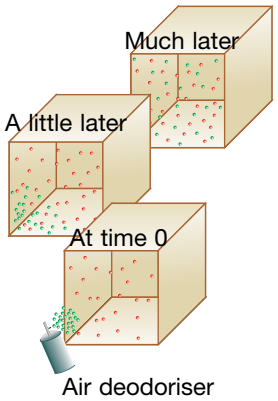
3.5 Going with the flow

3.5.1 Diffusion

The term 'fluid' is used to describe substances that can flow. This means that liquids and gases, which have particles that are much further apart and have more freedom of movement than those in solids, are both classified as fluids. They have some very special properties that are the result of this larger range of motion.

Diffusion is the spreading of one substance through another. This spreading occurs because the particles of each substance become mixed together. The movement of the particles in liquids and gases makes diffusion possible. Because the particles in a gas move faster than those in liquids, diffusion happens faster in a gas. Particles are not free to move in a solid, so diffusion cannot occur at all.

Spreading starts in an area where there is a concentration of one of the substances. The particles keep mixing through until they are evenly spread through each other.



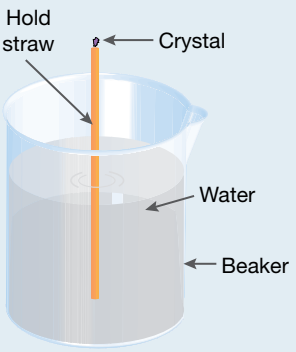
INVESTIGATION 3.5

Investigating diffusion

AIM: To investigate diffusion in liquids and gases

You will need:

500 mL beaker
water
straw
potassium permanganate crystals
fragrant spray
protective mat
safety glasses



- Using the straw as a guide, put a crystal of potassium permanganate in the bottom of a beaker of water. Remove the straw and record your observations.
- Release some of the fragrant spray in one corner of the classroom. Move away and observe by smell.

Discussion

1. Draw a diagram of the movement of the potassium permanganate through the water.
2. How do you think the fragrant spray moved through the air?
3. This experiment shows diffusion in a liquid (water) and diffusion in a gas (air).
   (a) Which state diffuses faster — liquid or gas?
   (b) Why do you think this is?

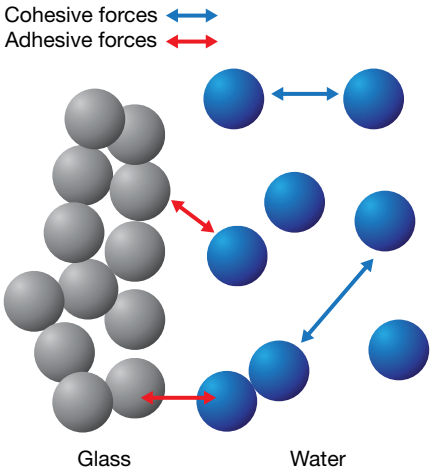
3.5.2 Sticking together

Adhesion and cohesion

Cohesive forces are attractive forces between similar particles in a substance whereas **adhesive forces** are attractive forces between particles of different substances. You may also see these forces referred to simply as **cohesion** and **adhesion**.

When water is poured into a glass, cohesive forces act between the water particles holding them together in the liquid. However, where the water particles are in contact with the glass, adhesive forces act between the water particles and the glass particles. The tug of war between adhesive and cohesive forces gives rise to many interesting effects.

Cohesion and adhesion acting on the particles of water and glass



3.5.3 Surface tension

At the surface of a liquid where it meets the air, the attraction between the particles is very strong, causing the surface to behave as if it had a thin skin over it — this is called **surface tension**. Light pond insects, such as water boatmen and pond skaters, use the surface tension of still water to essentially walk on the water!

The surface tension of the water is strong enough to allow this pond skater to move on it as if it were a solid surface.



Raindrops

When water droplets fall through the air, they form nearly perfect spheres as the strong cohesive forces acting between the water particles hold them tightly together. Water droplets on a bench surface, however, spread out because the adhesive forces acting between the surface and the water are stronger than the cohesive forces within the water droplets.

Water droplets on a bench surface



Strong cohesive forces hold raindrops in nearly perfect spheres.



INVESTIGATION 3.6

Observing surface tension

AIM: To investigate the effects of surface tension

You will need:

water
Petri dish
fine powder, such as baby powder or pepper
dishwashing liquid
toothpicks
eye-dropper
methylated spirits
clear plastic cup
2 needles
hand lens

Part A

- Fill the Petri dish nearly to the top with water and place it carefully on your bench.
- Gently shake the powder onto the water until the entire surface is covered with a fine layer.
- Dip the end of a toothpick into the dishwashing liquid, then touch the toothpick to the powdered surface. Observe what happens.
- Use the eye-dropper to draw up a small amount of methylated spirits. Add the methylated spirits to the powdered surface a drop at a time. Record your observations.

Part B

- Fill the plastic cup nearly to the top with water and place it carefully on your bench.
- Drop the first needle, point first, into the water and observe what happens.
- Take the second needle and carefully lower it horizontally onto the surface of the water — be careful that your fingers do not touch the water.
- Use the hand lens to examine where the needle and the water are in contact. Record your observations.
- Use the eye-dropper to add dishwashing liquid to the surface of the water near the needle, one drop at a time until the needle sinks.

Discussion

1. Describe the effects that the dishwashing liquid and the methylated spirits had on the powder in part A. Give a possible explanation for your observations.
2. Draw a labelled diagram to illustrate the appearance of the water where it was in contact with the floating needle in part B.
3. Explain in terms of surface tension why the needle delivered point first sank while the horizontally placed needle floated.
4. Using your observations from parts A and B, write a general statement on the effect of dishwashing liquid on surface tension.

Highly water-repellent surfaces (such as the one shown below) form such weak adhesive forces with the water particles that the strong cohesive forces within the water droplet easily pull the droplet back into a spherical shape.

Water droplet on a water repellent surface



3.5.4 Meniscus formation

As you will recall from Investigation 3.2, when a liquid is placed in a narrow vessel, such as a measuring cylinder or test tube, the surface curves to form a **meniscus**. A meniscus is formed because the cohesive forces between the particles of the liquid are not in balance with the adhesive forces between the liquid particles and the particles of the container.

Below is a picture of two different liquids — water and mercury — in glass test tubes. If you look closely you will see

that the meniscus of the water curves downwards while the meniscus of the mercury bulges upwards. So what's happening?

While the cohesive forces acting between water particles are strong, they are not as strong as the adhesive forces acting between water particles and glass particles. As a result, the adhesive forces pull the water upwards where it meets the glass. Mercury, however, has extremely strong cohesive forces between its particles, which are much stronger than the adhesive forces between mercury particles and glass particles. As a result, the mercury bulges upwards!

The meniscus of water is different from that of mercury.



HOW ABOUT THAT!

The surface tension of mercury is nearly seven times stronger than that of water at room temperature. Olive oil, on the other hand, has only half the surface tension of water.

3.5.5 Viscosity

Viscosity is a measure of how much resistance a fluid offers against movement. Water, which has a low viscosity, flows very easily when poured. Thick fluids like cold honey are very slow to move when poured and are said to have a high viscosity.

The viscosity of a fluid depends on how easily its particles are able to move over each other. The more easily particles move, the lower the viscosity. The viscosity of a fluid also controls how easily solids are able to move through them.

Pitch is a derivative of tar used in making bitumen roads; it has a very high viscosity. If you pick up a piece of pitch in your hand, it is hard and glassy to the touch and, if you hit it with a hammer, it shatters — all characteristics of a solid. Below is a photo of the famous pitch drop experiment set up by Professor Thomas Parnell at the University of Queensland in 1927 to demonstrate that 'solid' pitch is in fact a very, very thick liquid. The pitch is so thick (about 230 billion times less runny than water) that only one drop falls every twelve or so years!

Pitch is a very viscous liquid!



3.5 Exercise: Understanding and inquiring

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 cohesion?
2. **Define** the term 'viscosity'. Give two examples each of substances with (a) high viscosity and (b) low viscosity.
3. **Explain** why the meniscus of water is different from that of mercury when they are placed in identically shaped test tubes.
4. **Explain** how cohesion differs from adhesion.
5. **Describe** the effect that soaps and detergents have on the surface tension of a liquid.

Think

6. How are the forces between oil particles different from those in water?
7. **Explain** why a liquid cannot be compressed.
8. Can solids be considered to have surface tension? **Explain** your answer.
9. **Explain** which you think would be easier to swim in — a pool filled with water or a pool filled with honey.

Investigate

10. Design an experiment to test the effect of salinity on surface tension. Remember that salinity is a measure of how much salt is dissolved in water.
11. **Outline** the way in which you would test whether the viscosity of honey changes with temperature.
12. Many countries grade their motor oils for winter use: for example, 10W-30. Research what these numbers refer to, why they are important to know and whether we have a similar system of grading oil in Australia.

3.6 Changing states

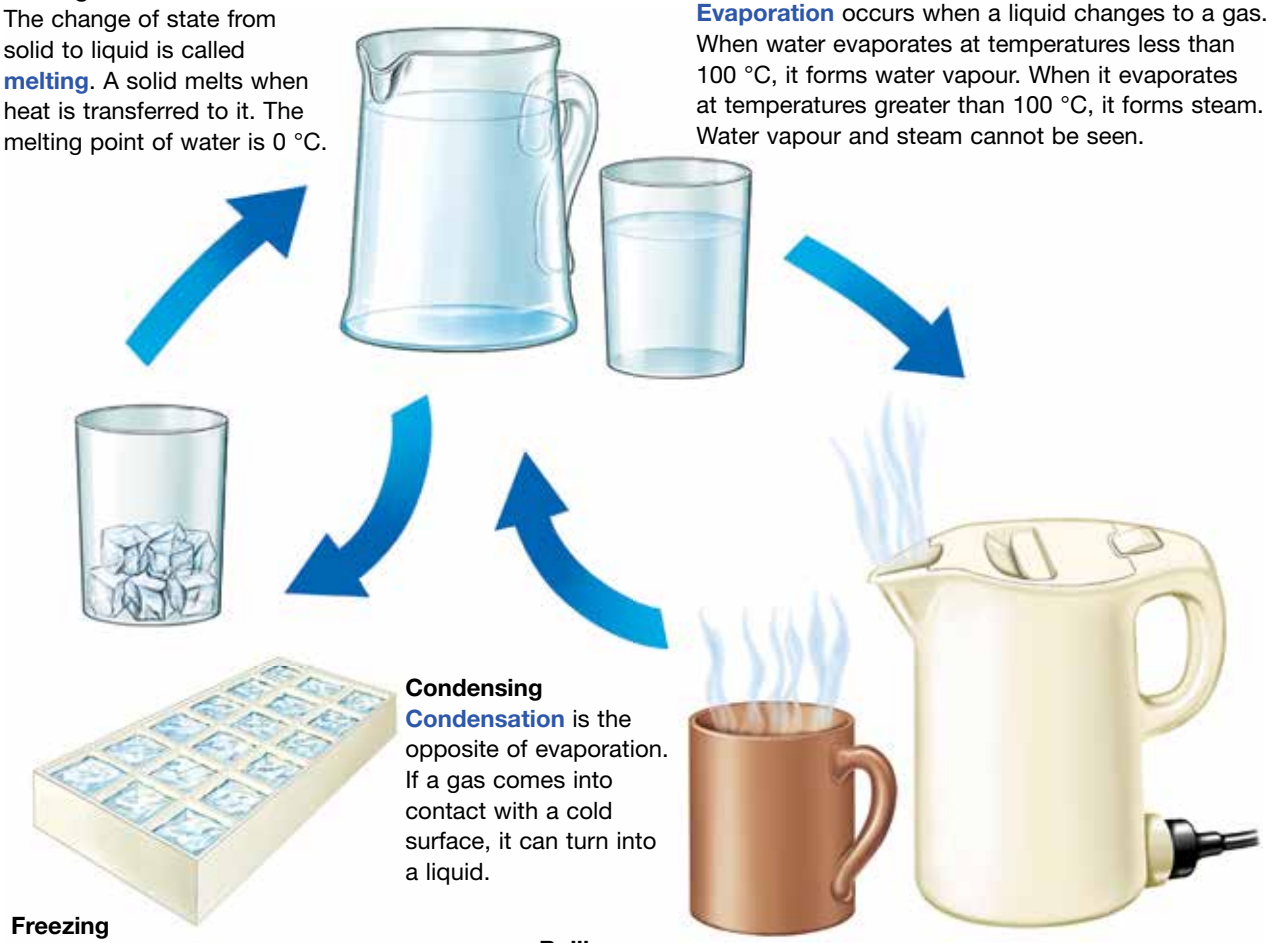
3.6.1 Heating and cooling

Many substances are usually found in one state of matter rather than another. For example, we are more likely to see table salt in its solid form rather than as a liquid or a gas, and we encounter gaseous oxygen a lot more often than we do solid oxygen.

However, this does not mean that the state of a substance must remain the same all the time. Most substances can be changed from one state of matter to another by either heating or cooling. Each of these changes has a particular term to describe it. Let's look at the changes of state that water undergoes when it is heated and cooled.

Melting
The change of state from solid to liquid is called **melting**. A solid melts when heat is transferred to it. The melting point of water is 0 °C.

Evaporating
Evaporation occurs when a liquid changes to a gas. When water evaporates at temperatures less than 100 °C, it forms water vapour. When it evaporates at temperatures greater than 100 °C, it forms steam. Water vapour and steam cannot be seen.



Condensing
Condensation is the opposite of evaporation. If a gas comes into contact with a cold surface, it can turn into a liquid.

Freezing
The change of state from a liquid to a solid is called **freezing**. A liquid turns into a solid when heat is transferred away from it. Water freezes at 0 °C.

Boiling
During **boiling**, the change from liquid to gas (evaporation) happens quickly. The change is so fast that bubbles form in the liquid as the gas rises through it and escapes. During boiling, the entire substance is heated. A liquid remains at its boiling point until it has all turned into a gas. The boiling point of water is 100 °C.

3.6.2 Sublimation

Some substances change from being a solid to being a gas without turning into a liquid in between. This unusual change of state is called **sublimation**. In the reverse process, **deposition**, a gas turns directly from gas to solid. The photo below shows solid carbon dioxide (known as dry ice) that has been added to water. The carbon dioxide is quickly sublimating from solid to gas. While it appears that the water is boiling, it is actually the carbon dioxide that is boiling and it is carbon dioxide gas in the white bubbles rising through the water. When the carbon dioxide gas reaches the air above the water, it cools the air so much that the water vapour in the air turns into tiny droplets of liquid water. These tiny droplets look like clouds or smoke.

Other substances including iodine and even diamond can also undergo sublimation. However, whereas dry ice sublimates at a temperature of 78.5 °C, diamonds sublimate at 3550 °C!

Dry ice in the water is turning from a solid into a gas. In the photo above the water has been coloured with blue dye to make the carbon dioxide bubbles more visible. The solid carbon dioxide is sitting at the bottom of the container.



INVESTIGATION 3.7

Observing changes of state

AIM: To investigate changes of state of water

You will need:

Bunsen burner, heatproof mat and matches
tripod and gauze mat
thermometer (–10 to 110 °C)
watch (with a second hand)
spoon
100 mL beaker
ice cubes
safety glasses

- Copy the table below into your notebook.
- Place four ice cubes (about 50 mL) in the beaker.
- Place the beaker containing the ice cubes on a gauze mat and tripod.
- Place the thermometer into the ice cubes and let it remain for a minute or so until the temperature stops changing. Take a reading and record this in your table under '0 minutes'.

Heating water

Time (minutes)	0	1	2	3	4	5	6	7	8	9	10
Temperature (°C)											

- Light the Bunsen burner and begin heating the ice cubes. Record the temperature each minute. Continue heating while the ice melts into water and while the water heats up. Stop when the temperature remains steady for three minutes.
- Hold the spoon in the vapour above the water and observe the effect.

CAUTION: Take care not to scald yourself with the hot water vapour.

Discussion

1. At what temperature was all the ice melted?
2. At what temperature did the liquid begin to bubble?
3. At what temperature did it boil?
4. What happened when the cold spoon was placed near the vapour?
5. What do you think was in the bubbles?

3.6.3 Melting point and boiling point

The state of matter of a substance depends on what temperature it is at, and how this temperature compares with its melting point and its boiling point. The **melting point** is the temperature at which a solid substance turns into a liquid (melts) or a liquid turns into a solid (freezes). The melting point of water is 0 °C, so water needs to be cooled to this temperature to turn it into ice. If you want to turn ice into water, you need to heat the ice until it is at 0 °C.

At the other end of the scale, the **boiling point** of a substance is the temperature at which it turns from a liquid to a gas quickly (boils) or turns from a gas into a liquid (condenses). The boiling point of water is 100 °C.

HOW ABOUT THAT!

Melting and boiling points change with the height above sea level. This is because the air gets thinner as you move away from the Earth's surface. If you were climbing Mount Everest and made a cup of coffee, you would find that the water would boil at about 70 °C.

The melting points and boiling points of substances can differ quite a lot as you can see in the table below.

Melting and boiling points of some common substances at sea level

Substance	Melting point (°C)	Boiling point (°C)
Water	0	100
Table salt	804	1413
Iron	1535	2750
Aluminium	660	1800
Oxygen	–218	–183
Nitrogen	–210	–196

INVESTIGATION 3.8

Changing the boiling point of water

AIM: To observe how impurities affect the boiling point of water

You will need:

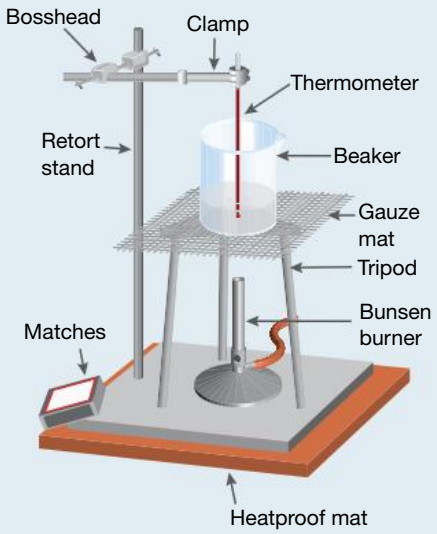
water
Bunsen burner
safety glasses
two 250 mL beakers
heatproof mat
thermometer
salt
matches
retort stand
sugar

tripod
bosshead and clamp
vinegar
gauze mat
teaspoon
100 mL measuring cylinder

- Copy the table below.

Water mixture	Time (min)										
	0	1	2	3	4	5	6	7	8	9	10
Tap water											
Salt water											
Sugar water											
Vinegar water											

- Set up the equipment as shown below. Put on your safety glasses.
- Measure 100 mL of water with the measuring cylinder and pour it into the beaker.
- Measure the starting temperature of the water (time = 0 min).
- Light the Bunsen burner and place it under the beaker. Measure the temperature of the water every minute for 10 minutes. Record your observations in the table.
- After 10 minutes, turn off the Bunsen burner and allow the equipment to cool.



- Repeat the previous steps with 100 mL of water with two teaspoons of salt stirred in, then 100 mL of water with two teaspoons of sugar stirred in, and lastly with 80 mL of water with 20 mL of vinegar stirred in.

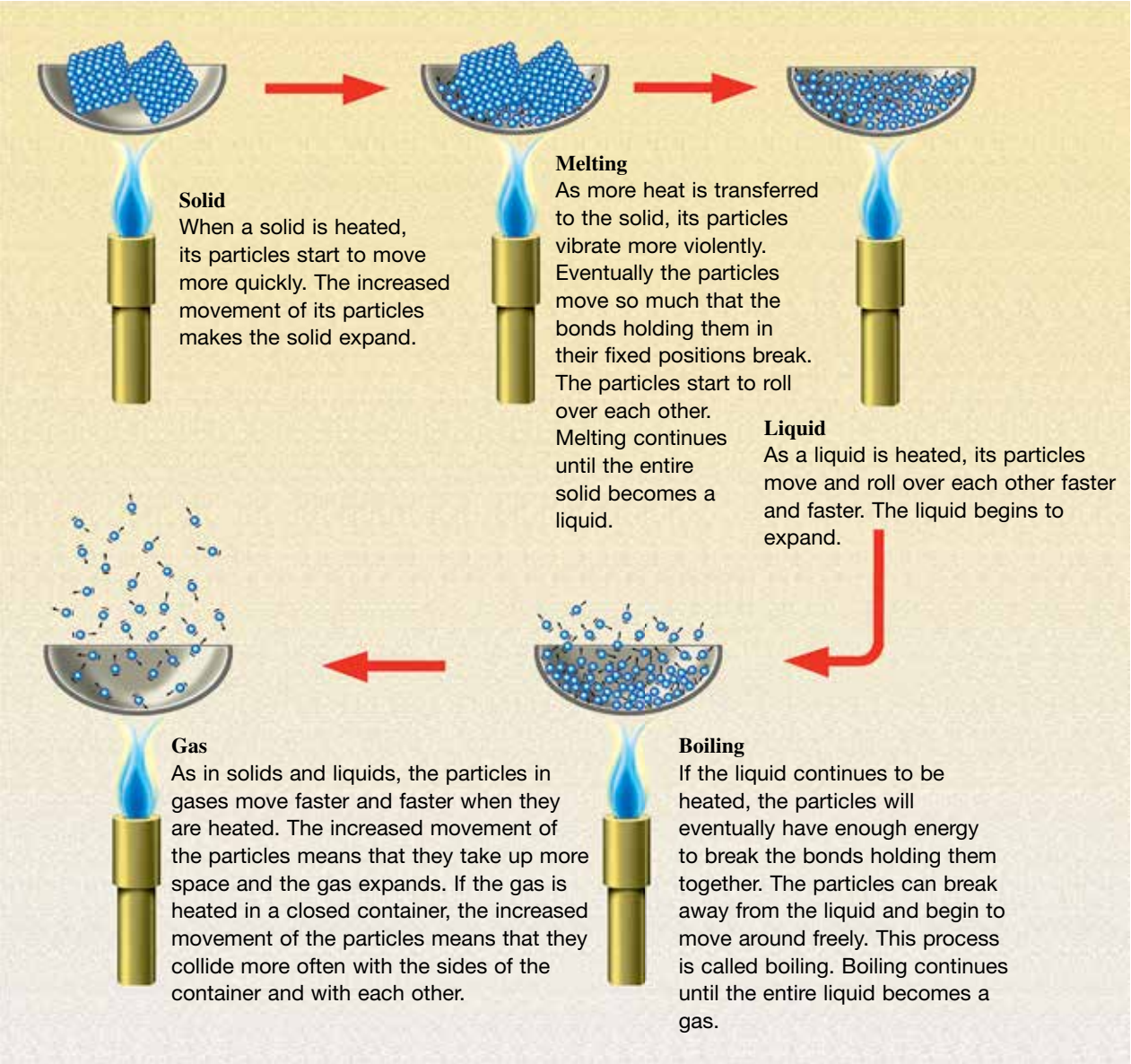
Discussion

1. Draw a line graph of your results. Use a different coloured line for each water mixture. Plot time on the horizontal axis and temperature on the vertical axis.
2. How can you tell when the water has reached its boiling point?
3. Is there any part of the graph that shows that the liquid has reached its boiling point?
4. What effect does adding substances to the water have on its boiling point?
5. What would happen to the temperature of each water sample if you continued to heat it past the 10-minute mark?

3.6.4 Change of state and the particle model

Imagine a very cold day. On days like this, you probably sit inside without moving around too much. As the weather gets warmer, you start to move around a little more. On warm, sunny days, you probably have a lot more energy. On these days, you might feel like moving about more. Much like you, the particles inside matter also change the way they move when they are heated or cooled.

A change of state involves the heating or cooling of matter. As a substance is heated, energy is transferred to it. When a substance cools, energy is transferred from it to another substance or to the environment. The change in energy causes the particles in the substance to move at different speeds.



3.6.5 Foggy mirrors

Have you noticed how the mirror in the bathroom 'fogs up' after a hot shower? The 'fog' is actually formed when water vapour that evaporates from the hot water cools down.

Fog in the air
Some of the energy of the particles in the water vapour is transferred away from the vapour to the air. The transfer of energy leaves the water vapour with less energy — so much less energy that its particles slow down. The transfer of energy away from the water vapour means it cools down and turns into tiny droplets of water. These tiny droplets form clouds. This process is called condensation.

Invisible gas
Water vapour forms when particles in the hot water gain enough energy to escape and become a gas. You can't see water vapour. The particles in the water vapour move around freely. They have more energy than the particles in the liquid water.



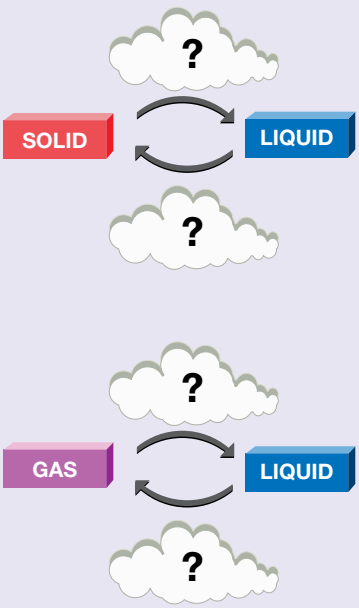
Fog on the mirror
The energy from some of the water vapour is transferred to the cold mirror. This causes the water vapour to condense to form tiny water droplets.

3.6 Exercise: Understanding and inquiring

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 diagram below, **identifying** the changes of state.



2. **Recall** the name given to the change of state from liquid water to water vapour. **Describe** how this happens.
3. **Explain** what happens to liquid water when it is cooled below 0 °C. Has heat moved into or out of the liquid?
4. **Describe** what happens to the motion of particles in a solid as it becomes a liquid.
5. **Describe** what happens to the motion of gas particles as a gas condenses.
6. **Recall** why substances often expand when they are heated.

Think

7. **Explain** why dry ice is useful to produce a 'smoke' effect. What other uses are there for dry ice?
8. **Explain** why solid blocks of air freshener disappear without a trace within a few weeks of use.
9. **Identify** the substance that is in the bubbles that you see when water is boiling.
10. In movies, you sometimes see a pocket mirror being held in front of the mouth or nose of someone on the ground to test whether they are breathing. **Explain** why this would work.
11. For the following processes, **identify** which involve adding energy to the particles in a substance and which involve transferring heat away from the particles.
    (a) Melting
    (b) Condensation
    (c) Boiling
    (d) Freezing
    (e) Sublimation
    (f) Evaporation

Analyse

Use the table of Melting and boiling points to answer the following questions.

12. (a) At what temperature would you expect table salt to transform from a solid into a liquid?
    (b) At what temperature does it solidify?
13. Would you expect aluminium to be a solid, a liquid or a gas at:
    (a) 200 °C
    (b) 680 °C
    (c) 1900 °C?
14. Oxygen and nitrogen gas are placed in a sealed container and the temperature of both gases is slowly dropped. Which of the two gases will be the first to freeze?

Design

15. The following letter was written to a household help column in a popular magazine.
    Dear Handy Hints,
    I am sick and tired of having to wait for my bathroom mirror to demist after I've had a shower so I can get ready for work. Is there any way I can stop my mirror from fogging up?
    No Foggy Idea
    Design investigations to test the following.
    (a) Mirrors fog up only if they are colder than the water coming from the shower.
    (b) Clean mirrors fog up less than dirty mirrors.
    (c) Mirrors that are covered with lemon juice don't fog up.
16. Use the **Changes of state** interactivity in the Resources tab to simulate heating over a Bunsen burner.

learnON RESOURCES — ONLINE ONLY

Complete this digital doc: Worksheet 3.2: Boiling liquids (doc-12361)

Complete this digital doc: Worksheet 3.3: Changes of state (doc-12362)

Try out this interactivity: Changes of state (int-0222)

3.7 Density

3.7.1 What is density?

When a cork is dropped into a glass of water, it floats at the water surface. If you drop an iron nail into a glass of water, it sinks to the bottom almost immediately. However, huge iron ships that weigh billions of times more than that nail are able to float in an ocean without a problem. So what exactly is going on? Why do some things float and others sink in water?

All materials, whether solid, liquid or gas, can be described in terms of a property called **density**. Density is a measure of how much matter there is in an object (its mass) compared with how much space it takes up (its volume). The density of an object depends on how closely packed together its particles are.

How is this ship able to float when an iron nail sinks?



3.7.2 Calculating density

You can determine the density of an object by dividing its mass by its volume:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

The units that we use for the density of an object depend on the units used for its mass and for its volume.

- If the mass is in grams (g) and the volume is in cubic centimetres (cm^3), the density is measured in g/cm^3.
- If the mass is in kilograms (kg) and the volume is in cubic metres (m^3), the density is measured in kg/m^3.

The density for fluids is often given in g/mL, where the fluid's mass has been measured in grams and the fluid's volume in millimetres.

Example

A piece of steel has a volume of 12 cm^3 and a mass of 91.2 grams. What is the density of steel?

$$\begin{aligned}\text{Density of steel} &= \frac{\text{mass}}{\text{volume}} \\ &= 91.212 \\ &= 7.6\end{aligned}$$

As the mass was given in grams and the volume in cm^3, the density is in g/cm^3. So, we say that the density of steel is 7.6 g/cm^3.

Different materials have different densities, as shown in the table below.

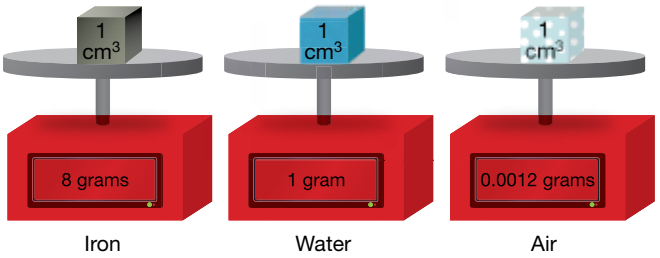
Material	Density (g/cm^3)
Gold	19.3
Copper	8.96
Diamond	3.52
Window glass	2.8
Water	1.00
Vegetable oil	0.92
Methylated spirits	0.8
Air*	0.001 2
Helium*	0.000 18

*At standard atmospheric pressure

The densities of these materials are measured in grams per cubic centimetre so we can also see that density is equal to the number of grams that a cubic centimetre of that material weighs.

For example, the density of iron is 8 g/cm^3, so a cubic centimetre of iron would weigh 8 grams. In comparison, a cubic centimetre (or one millilitre) of water would weigh 1 gram while a cubic centimetre of air would weigh 0.0012 grams — or 1.2 milligrams!

Density describes the mass of a cubic centimetre of material.



3.7.3 Sinking and floating

An object floats in a fluid provided that it has a lower density than the fluid does.

Cork, with a density of about 0.2 g/cm^3 has a density much less than that of water and so it floats in water. Iron's density is much greater than that of water, so an iron nail sinks. So what about our ship?

Remember that density is related to the total mass of an object compared with how much space it takes up. If all of the iron in a ship were packed together into a solid mass, it would sink like a rock to the bottom of the ocean. However, the iron in a ship has been beaten out into thin sheets to form the hull and the other parts of the ship, giving it a much larger volume, most of which is air. This means that the overall density of the ship (its mass compared with its volume) is lower than that of water. The result — the ship floats!

HOW ABOUT THAT!

The density of blood is 1.06 g/cm^3, bone has a density of 1.85 g/cm^3, body fat has a density of 0.92 g/cm^3 and muscle tissue has a density of 1.05 g/cm^3. On average, the human body has an overall density roughly the same as that of water, so we usually float. However, some people are almost incapable of floating, usually because they have a larger muscle mass and smaller fat percentage than the average person. These people, having a higher average density than water, are said to have negative buoyancy. At the other extreme, some people have positive buoyancy and float with much more of their bodies above the waterline than the average person.

Some people find it harder to float than others!



INVESTIGATION 3.9

Sinking ships

AIM: To investigate how density affects buoyancy

You will need:
a ball of plasticine
a bucket of water
plastic cup

- Half-fill the bucket with water.
- Roll the plasticine into a ball and place it carefully on the surface of the water. Let it go and watch what happens.

- Retrieve the plasticine and now shape it so that it forms an open bowl (ship). Test to see if it floats in the water. You may need to adjust the shape of the plasticine ship a few times until it is able to float.
- Now, fill the cup with water and pour it into the floating ship until it is full of water.

Discussion

1. Describe what happened to the plasticine ball when you put it in the water.
2. Compare the volume (the amount of space that is taken up) of the floating ship with that of the ball.
3. The mass of the plasticine has not changed. Which of the two shapes has the lower overall density?
4. Explain why the plasticine ship sank when it was filled with water.

Floating fluids

Fluids can float on top of other fluids, with the less dense fluid on the top. Oil is less dense than water. This is why oil spilled from wrecked tankers floats on the top of the ocean.

Cooking oil is less dense than water so it floats on top.



INVESTIGATION 3.10

Sinking and floating

AIM: To observe the behaviour of a mixture of liquids with different densities

You will need:

250 mL beaker
3 test tubes
test-tube rack
20 mL measuring cylinder
brown vinegar
water
olive oil
honey

- Pour 20 mL each of vinegar, olive oil and honey into separate test tubes.
- Add 20 mL of water to each test tube.
- Pour 20 mL each of vinegar, olive oil and honey into the beaker.
- Let the test tubes and the beaker sit undisturbed for 30 minutes.

Discussion

1. How could you tell if a particular liquid was less dense or more dense than water?
2. Which of the liquids were denser than water?
3. Which of the liquids were less dense than water?
4. Draw a labelled diagram showing the order of the layers formed in the beaker.
5. Based on what you saw in the beaker, which was the:
   (a) densest liquid
   (b) least dense liquid?

3.7 Exercise: Understanding and inquiring

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 the units of density would be if:
   (a) mass is in kilograms and volume is in cubic metres
   (b) mass is in grams and volume is in millimetres
   (c) volume is in cubic centimetres and mass is in kilograms.
   (*Note:* This density unit is usually used only with extremely dense objects such as neutron stars!)
2. If you take a bottle of salad dressing out of the fridge, you may notice that the oil and the vinegar have separated into different layers. **Explain** why this occurs.

Think

3. **Explain** why most people float in water.
4. **Explain** why balloons filled with helium float upwards.
5. **Describe** the general relationship you notice between a substance's state of matter and its density. (Use the table of densities as a guide.)
6. Equal amounts of vegetable oil, water and methylated spirits are poured into a jar. **Identify** which liquid will form:
   (a) the top layer
   (b) the lowest layer.
7. When divers breathe out under water, the air bubbles head straight to the surface. **Deduce** why this happens.

Calculate

8. Use the density equation to **calculate** the missing values in the following table.

Mass (g)	Volume (cm^3)	Density (g/cm^3)
10	5	
	40	0.5
600		15

9. **Explain** why this ship is sinking in the water when the boat in the background of the photo is still afloat.



10. Select liquids and solids in the **Density** interactivity in the Resources tab and see what sinks and what floats.

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Complete this digital doc: Worksheet 3.4: Density (doc-12363)

Complete this digital doc: Worksheet 3.5: Density and flotation (doc-12364)

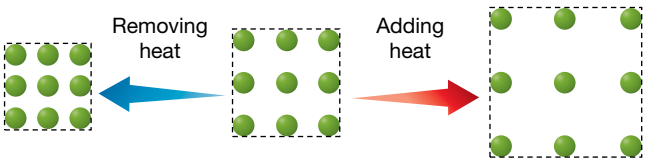
Try out this interactivity: Density (int-0221)

3.8 Expansion and contraction

3.8.1 The particle model: expansion

The particle model can be used to explain changes in the size of a substance as well as changes in its state. When a substance is heated, the particles move faster, becoming further apart and taking up more space. The substance **expands**.

The volume of a substance changes when it is heated or cooled.



Contraction
- Particles move more slowly.
- Distance between particles gets smaller.
- The attraction between the particles increases.

Expansion
- Particles move faster.
- Distance between particles increases.
- The attraction between the particles decreases.

3.8.2 A bit of a stretch

The tyres on a moving car get quite hot. This makes the air inside expand. This may even cause a blowout in extreme circumstances. Gases usually expand much more than solids or liquids. Gases expand easily because the particles are spread out and not strongly attracted to each other. Almost all solids, liquids and gases **contract** when they are cooled again because the particles slow down, need less space to move in and become more strongly attracted to each other.

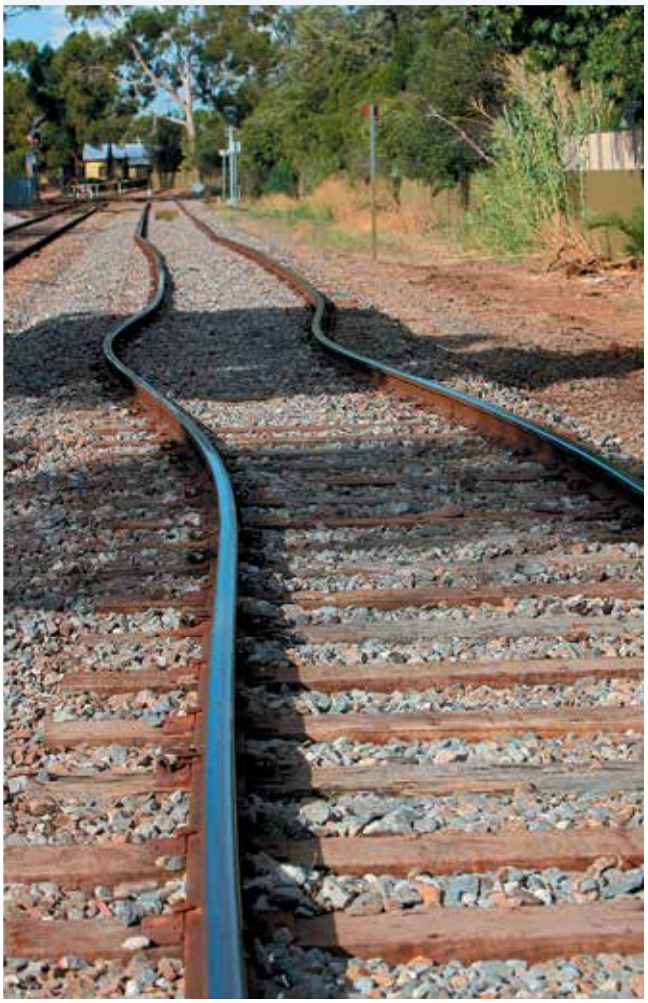
Architects and engineers allow for expansion and contraction of materials when designing bridges and buildings. Bridges have gaps between large sections so that in hot weather, when the metal and concrete expand, they do not buckle. Railway lines also have gaps to allow for expansion in hot weather.

HOW ABOUT THAT!

The Sydney Harbour Bridge is, on average, 18 cm longer in summer than in winter due to thermal expansion and contraction of the steel from which it is made.

Electric power lines are hung from poles loosely so that, in cold weather, they do not become too tight and break as they contract. The amount by which each structure expands or contracts depends on the material it is made from; so, when choosing a material for a special purpose, it is important to find out how much that material will expand or contract. The table below shows how much some commonly used materials expand when the temperature increases by 10 °C.

Railway lines in Melbourne buckled so much due to unexpectedly high temperatures in January 2010 that trains could not travel along them.



Expansion of 100 m length of materials when temperature increases by 10 °C

Substance	Steel	Iron	Platinum	Brass	Concrete	Glass — soda	Glass — Pyrex	Lead	Tin	Aluminium	Bronze
Expansion (mm)	11	12	9	19	11	9	3	29	21	23	18

INVESTIGATION 3.11

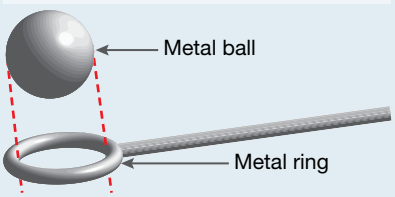
Expansion of solids

AIM: To demonstrate expansion and contraction of solids

You will need:

metal ball and ring set
Bunsen burner
heatproof mat
tongs

A ball and ring set



- Try to put the ball through the ring.
- Use the Bunsen burner to heat the ring and use tongs to try to put the ball through it. Take care not to touch the hot metal.
- Let the ring cool and try to put the ball through the ring again.

Discsussion

1. What has happened to change the size of the ring?
2. Use the particle model to explain the change that took place in the ring.

3.8.3 Thermometers

Liquids expand more than solids. This property makes them useful to use in thermometers. Most thermometers consist of thin tubes, and a bulb that contains a liquid. As the temperature rises, the liquid expands, moving up the tube. In a thermometer, the tube is sealed at the top.

The two most commonly used liquids for thermometers are mercury and alcohol. Mercury has a low freezing point (−39 °C) and a high boiling point (357 °C). Alcohol, however, is much more useful in very cold conditions because it does not freeze until the temperature drops to −117 °C. On the other hand, alcohol boils at 79 °C so it cannot be used for measuring higher temperatures.

The temperature of the human body ranges between 34 °C and 42 °C; it is normally about 37 °C. A clinical thermometer is especially designed to measure human body temperature.

The Galileo thermometer

A Galileo thermometer is made up of small glass balls, each filled with a coloured liquid, floating in a sealed tube filled with clear liquid. Each of these balls has a disc attached to it with a temperature printed on it. As the air temperature changes, the clear liquid expands and contracts, changing its density. The balls that have a higher density than the liquid sink, while those with a lower density rise. The temperature of the liquid (and the air) is read from the disk on the lowest ball of the floating group.



This Galileo thermometer shows that the temperature is 22 °C. You can see that the balls above the 22 °C ball, are labelled 24 and 26. What do you think the temperature indicated on the purple ball at the bottom of the thermometer might be?

INVESTIGATION 3.12

Expansion of liquids

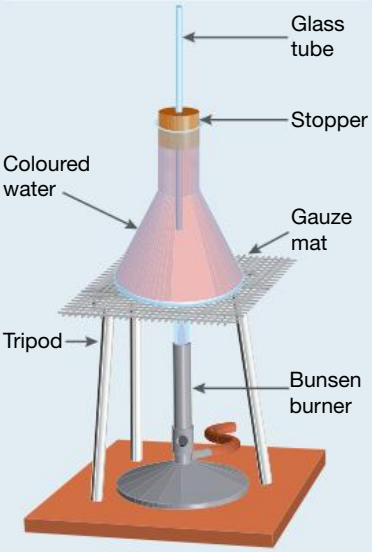
AIM: To investigate expansion and contraction of liquids

You will need:

500 mL conical flask
narrow glass tube
rubber stopper with one hole to fit the tube
Bunsen burner
heatproof mat and matches
tripod
gauze mat
food colouring
eye-dropper
marking pen

- Use an eye-dropper to put two or three drops of food colouring in the conical flask and fill it with water right to the top.

Investigating the expansion of liquids



- Place the stopper in the flask with the tube fitted. Some coloured water should rise into the glass tube. Mark the level of the liquid in the tube with the marking pen.
- Place the flask on the tripod and gauze mat, light the Bunsen burner and gently heat the liquid.
- After about five minutes of heating, turn off the Bunsen burner and watch what happens to the level of the liquid in the glass tube.

Discussion

1. What happens to the level of the liquid while it is being heated?
2. What happens to the level of the liquid while it is cooling down?
3. Use the particle model to explain why liquids expand.

3.8 Exercise: Understanding and inquiring

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. When a substance is heated, its temperature increases. **Describe** what other change might be observed.
2. (a) **Recall** what change you would expect to see when hot metal objects are cooling.
   (b) Why does this happen? **Explain** using the particle model.
3. Give two examples of structures that contain gaps to prevent them from buckling in hot weather.
4. Give one reason why overhead electric power lines are not hung tightly.

Analyse

Use the table on page 110 to answer questions 5 to 7.

5. If a steel rod of 10 metres in length is heated so that its temperature rises by 10 °C, **calculate** how long the rod would become.
6. **Explain** why Pyrex, rather than soda glass, is used in cooking glassware such as casserole dishes and vision saucepans.
7. Concrete is often reinforced with steel bars or mesh to make it stronger. **Explain** why steel is a better choice than another metal, such as aluminium or lead.

Think

8. A jar with the lid jammed on tightly can be hard to open. If hot water is run over the lid, it becomes easier to open. **Deduce** why.
9. Hot-air balloons have a gas heater connected to them. The pilot can turn the heater on and the balloon will go higher.
   (a) **Explain** why.
   (b) **Describe** how the balloon could be brought lower.
10. Under what conditions might you use an alcohol thermometer rather than a mercury thermometer?

Investigate

11. The mercury thermometer was invented by a German named Gabriel Fahrenheit (1686–1736). A different set of markings is used to scale Fahrenheit thermometers. **Investigate** the temperatures at which water boils and freezes on this scale.
12. **Explain** why icebergs float in Arctic and Antarctic waters. Do you think there is much of the iceberg under the water, or is it mostly above? How could you test out your hypothesis? Design a suitable experiment.
13. All materials expand when heated and contract when cooled, right? Use the **Mystery expansion** weblink in the Resources tab to learn about a substance that breaks all the rules.

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Complete this digital doc: Worksheet 3.6: Expansion of liquids (doc-12365)

Explore more with this weblink: Mystery expansion

3.9 Under pressure!

3.9.1 Fighting fire

'The firefighter charged through the doors just in time, pointed the extinguisher at the electrical fire and pressed the trigger. A huge burst of carbon dioxide gas came squirting out of the nozzle, putting out the flames.'

The carbon dioxide in the story above could be used in this way only because huge amounts of it can be compressed, or squeezed, into a container. Gases can be compressed because there is a lot of space between the particles. Gases compressed into cylinders are used for barbecues, scuba diving, natural gas in cars, and aerosol cans.





3.9.2 Hot air balloons

Hot-air balloons work on the idea that gases expand when heated. The particles in the heated gas move about more and take up more space.

This makes each cubic centimetre of hot air in the balloonlighter than each cubic centimetre of air outside the balloon, so it rises, taking the balloon with it.



4 When the nozzle is opened, the pressure **forces** the carbon dioxide gas out very quickly through the opening.

5 The particles of gas quickly spread out over the fire. The gas smothers the fire, stopping oxygen from the air getting to it. Fires cannot burn without oxygen, so the fire goes out.

1 Gases, including carbon dioxide, have lots of space between their particles.

2 The carbon dioxide is compressed into the cylinder. The particles are squashed closer together.

3 The carbon dioxide particles are now under increased **pressure**. This means that the particles in the gas collide frequently with the walls of the cylinder. The particles push outwards on the walls of the cylinder. The particles are trying to escape, but are held in by the container.

3.9.3 Fizzing drinks



All carbonated soft drinks contain carbon dioxide gas. The gas is dissolved in the liquid under high pressure. The gas stays dissolved in the liquid as long as the pressure inside the can is higher than outside the can. When the can is opened, it is de-pressurised and the carbon dioxide starts rising to the surface (because it is less dense than the liquid). In its hurry to escape, the carbon dioxide often pushes the top layer of liquid out as well, causing it to fizz and spill.

Well-known gases

There are many gases we use for different purposes. Here are some of the more well-known ones.

Famous gas	Use	Property
Neon	Neon lights	Absorbs electrical energy and turns it into light
Helium	Party balloons, blimps	Lighter than air
Methane (in natural gas)	Cooking, heating	Flammable
Argon	Fluorescent lights	Absorbs electrical energy and turns it into light
Ozone	Cleaning water in pools and spas	Highly reactive; kills bacteria
Nitrous oxide (laughing gas)	Anaesthetic	Affects nervous system in humans

INVESTIGATION 3.13

Exploring gases

AIM: To investigate expansion and contraction of gases

You will need:
small balloon
string
ruler
large beaker
warm water
cold water or fridge

- Blow up the balloon until it is firm.
- Measure the circumference of the balloon with a piece of string and record your results in a table.
- Put the balloon in warm water for 10 minutes and re-measure the circumference.
- Put the balloon into the cold water or a fridge for 10 minutes and measure the circumference of the balloon again.

Discussion

1. Did the balloon expand or contract in warm water?
2. Did the balloon expand or contract in the cold water or a fridge?
3. Explain, in terms of particles, what happened when the balloon was heated and cooled.

3.9 Exercise: Understanding and inquiring

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 gases can be compressed.
2. **Describe** what happens to a gas that is heated.
3. **Explain** how a carbon dioxide fire extinguisher works.

Think

4. Draw a diagram of a gas before and after heating to show what happens to the particles.
5. **Explain** why aerosol cans have 'Do not dispose of in fire' printed on the can.
6. Infer which would last longer: a scuba diver's tank filled with compressed air or one filled with air at normal pressure.
7. **Explain** what would happen to the pressure in a car tyre after it has been driven on a hot road and then parked on some cool grass.

Investigate

8. Many gases, including oxygen, nitrogen, chlorine and hydrogen, have important uses. Choose one of these gases and **investigate** what it is used for and why.
9. **Investigate** which gases are found in the air and how much of each gas there is.
10. Many gases in the air are pollutants put there by humans. **Investigate** the problem one of the following gases causes to the environment.
    sulfur dioxide, chlorofluorocarbons (CFCs), nitrogen dioxide, ozone

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Complete this digital doc: Worksheet 3.7: Particles in our lives (doc-12366)

Watch this eLesson: Under pressure (eles-0058)

3.10 Plasma — the fourth state of matter

Science as a human endeavour

3.10.1 How is plasma made?

Lightning turns gases in the air into plasma at temperatures higher than 1 000 000 °C.



In the past, scientists believed that everything around us was either a solid, a liquid or a gas. But scientists now believe that there are other states of matter that are not very common on Earth.

The earliest of these additional states of matter to be identified is called **plasma**. It is currently estimated that more than 99 per cent of all matter in the universe is actually plasma. Plasma occurs everywhere. The sun and all the other stars are made of plasma, as are lightning and the aurora australis (also known as the southern lights). Temperatures higher than 1 000 000 °C are needed to form these plasmas. Lightning bolts actually form plasma from the surrounding air.

In an ordinary gas, each **atom** contains an equal number of **protons** and **electrons**. (We will learn more about the particles that make up the atom in topic 9.) This makes each atom neutral. The positively charged protons are surrounded by an equal number of negatively charged electrons. A gas becomes plasma when energy or heat is added. This energy or heat causes the atoms to release some or all of the electrons. This means that the remaining atoms now have fewer electrons and the atoms have a positive charge. The removed electrons are free to move about.

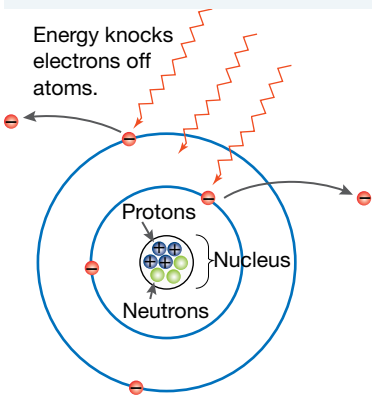
3.10.2 Plasma properties

Plasmas have different properties from gases. For example, oxygen gas is not affected by magnetic fields and cannot conduct electricity. However, if oxygen gas is turned into plasma, it can be contained in a magnetic field and can conduct electricity.

Different atoms form different types of plasma. Each type of plasma can be used for different purposes, such as in neon lights and fluorescent tubes. Plasmas are also used in lasers, high-powered microwaves, water purification and some semiconductors in computers.

Scientists are currently studying how plasmas could be used to release energy from sea water without creating pollution. A possible solution is, firstly, to use sea water to make hydrogen gas. The atoms of hydrogen gas could then be joined together (fused), a process that releases large amounts of energy.

Incoming energy removes electrons from gas atoms, changing them into a plasma state.



Plasmas are used in lasers.



However, this fusion occurs at such high temperatures that there is currently no container on Earth that could hold the plasma without being destroyed. The good news though is that, because plasma is affected by magnetic fields, a special magnetic container may be able to hold the plasma.

3.10 Exercise: Understanding and inquiring

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 naturally occurring plasma.
2. Atoms in solids, liquids and gases are neutral. **Explain** what this means.
3. What happens to the atoms in a gas to make them into plasma? **Explain** this in terms of protons and electrons.
4. **Describe** a current use of plasma.
5. **Recall** some examples of how plasma may be used in the future.

Think

6. **Distinguish** between the properties of a plasma and those of a gas.
7. Draw a diagram using particles to **demonstrate** what happens if a substance changes from a solid to a liquid to a gas to a plasma.
8. **Explain** why scientists think that plasma would be a good energy source in the future.

Investigate

9. **Investigate** how a neon light works. Present your findings as an advertisement to sell a new neon light.

3.11 Review

3.11.1 Study checklist

States of matter

- **identify** the three most common states of matter **3.2**
- **describe** the physical properties of solids, liquids and gases **3.2**
- **explain** what is meant by the term 'fluid' **3.5**
- **explain** density in terms of the particle model **3.7**
- **describe** the changes in pressure of gases in terms of the increase or decrease of frequency of particle collisions **3.9**
- **describe** the state of matter called plasma **3.10**
- **describe** current research on the use of plasma in energy production **3.10**

The particle model of matter

- **state** the main assumptions of the particle model **3.3**
- **describe** the difference in behaviour of particles in solids, liquids and gases **3.3, 3.4, 3.5**
- use the particle model to **explain** expansion and contraction of materials during heating and cooling **3.8**
- **discuss** how increasing and decreasing the energy of particles affects their movement **3.3, 3.4**
- **describe** what happens during the process of diffusion **3.2, 3.5**

Changes of state

- **describe** the physical changes that occur during sublimation, evaporation, condensation, boiling, melting and freezing **3.6**
- **relate** changes of state to the motion of particles as energy is added or removed **3.6**
- **explain** the changing behaviour of particles during changes of state **3.6**

Individual pathways

ACTIVITY 3.1
Revising states of matter
doc-10537

ACTIVITY 3.2
Investigating states of matter
doc-10538

ACTIVITY 3.3
Investigating states of matter further
doc-10539

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FOCUS ACTIVITY

A mysterious substance is developed in a laboratory. The sample has a mass of 10 g and has a volume of 2.3 cm^3.
(a) **Calculate** its density.
(b) What is the mystery substance's most likely state of matter?
Access more details about focus activities for this topic in the Resources tab (doc-10536).

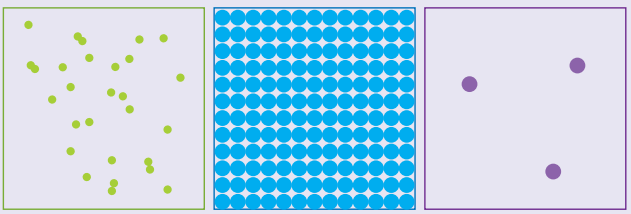
3.11 Review 1: Looking back

assessON

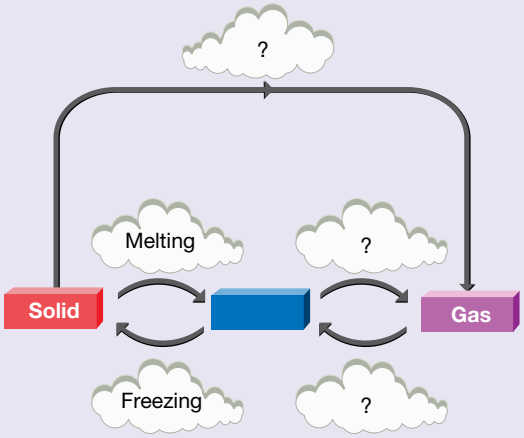
1. Use the particle model to **explain** why steam takes up more space than liquid water.
2. **Recall** in which state the forces of attraction between the particles are likely to be greatest.
3. **Identify** in which state — solid, liquid or gas — the particles have:
   (a) the most energy
   (b) the least energy.
4. **Explain** why perfume and aftershave lotion evaporate more quickly than water.
5. Copy and complete the table below to **summarise** the properties of solids, liquids and gases. Use a tick to indicate which properties each state *usually* has.

Property	Solid	Liquid	Gas
Has a definite shape that is difficult to change			
Takes up a fixed amount of space			
Can be poured			
Takes up all of the space available			
Can be compressed			
Is made of particles that are strongly attracted to each other and can't move past each other			
Is made of particles that are not held together by attraction			

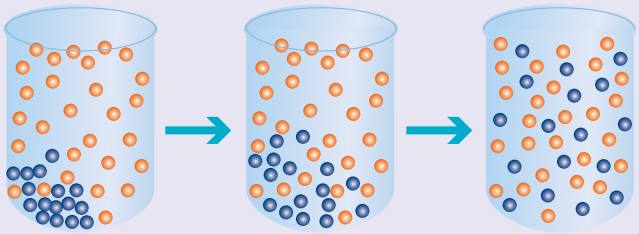
6. Copy and label the three diagrams below to **identify** which represent solids, liquids and gases. Make an improvement to each of the diagrams so that they describe the particle model more fully.



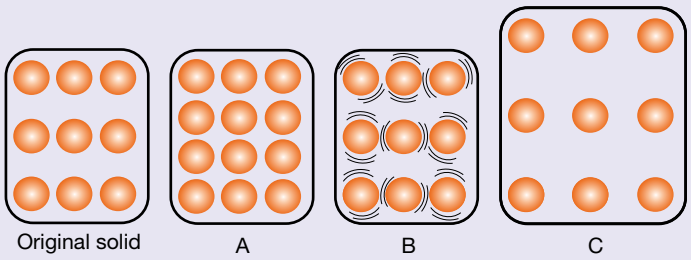
7. Copy and complete the diagram below, labelling the missing state and changes of state.



8. Fully **explain** the process that is occurring in the following diagrams.



9. **Identify** which of these diagrams (A, B or C) correctly shows a solid after expanding.



10. (a) Copy the table below and rewrite it to correctly match the substances to their properties and uses.
(b) **Identify** whether the substance would be a solid, liquid or gas.

Properties and uses of various substances

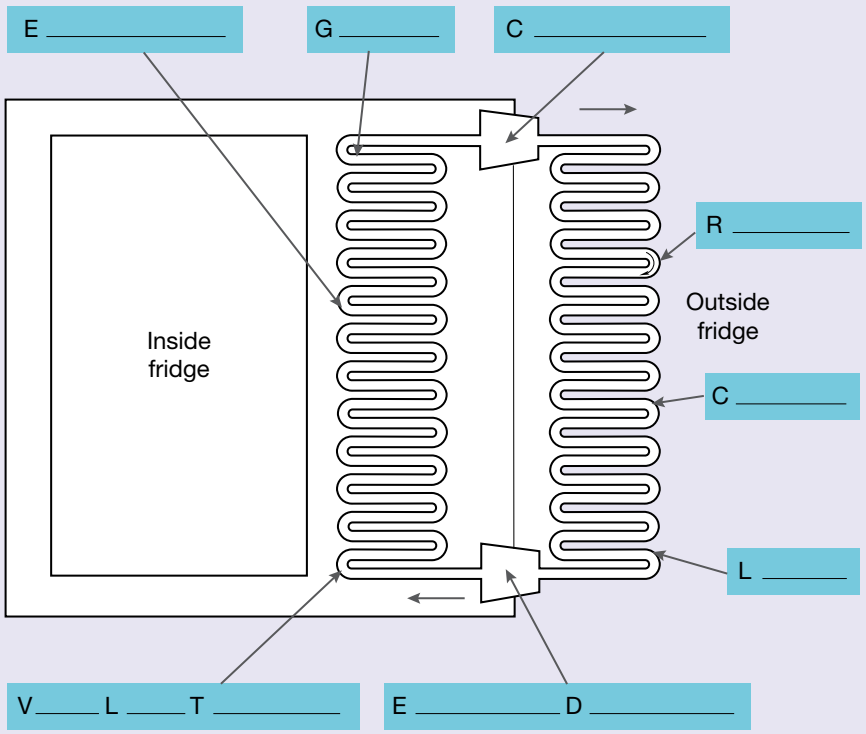
Name of substance	Property	Use	Solid, liquid or gas?
Air	Waterproof, hard, strong	Horseshoe	
Tin	Particles able to mix easily with other particles	Balloon	
Neon	Particles absorb energy and turn it into light	Sign, light	
Oil	Hard, strong	Driveways	
Iron	Hard, strong, easily shaped when heated	Lubricant	
Concrete	Particles slip past each other	Roofing	

11. Graphite (used in pencils) and diamond are both made of the same type of particle, yet graphite has a density of 1.46 g/cm^3 while diamond has a density of 3.52 g/cm^3. Give possible explanations for how they can have different densities yet be made of identical particles.

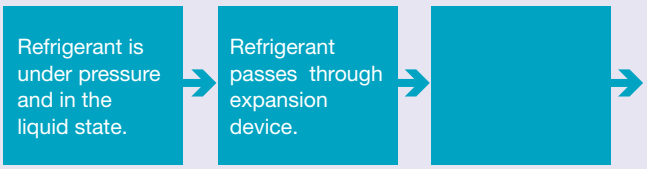
12. **Compare** and **contrast** mercury and alcohol thermometers.
13. A metalworker wishes to ensure that a rivet joining two pieces of steel won't loosen. He decides to make the rivet hole slightly smaller in diameter than the rivet.
    (a) In order to get the rivet to fit, which will need to be heated — the rivet or the steel around the hole? **Explain** your answer in terms of the particle model.
    (b) What are the disadvantages of using this method to join sections of metal?
14. In what ways does the particle model of matter fall short of describing the real behaviour of matter?

Test yourself

1. 'Compression' is a term that describes
   (A) squeezing the particles of a substance closer together.
   (B) pulling particles further apart.
   (C) removing the heat energy from the particles of a substance.
   (D) the releasing of air from a car tyre. **(1 mark)**
2. Ice cubes float in soft drink because
   (A) the bubbles in the soft drink hold them up.
   (B) the ice is less dense than the soft drink.
   (C) the ice is denser than the soft drink.
   (D) water and soft drink do not mix. **(1 mark)**
3. According to the particle model, the attractive forces between particles are strongest in
   (A) solids.
   (B) liquids.
   (C) gases.
   (D) plasma. **(1 mark)**
4. Gaps are left between sections of railway track so that
   (A) more track can easily be laid later.
   (B) bugs can cross the railway lines safely.
   (C) the steel tracks can expand in cold weather without buckling the track.
   (D) the steel tracks can expand in hot weather without buckling the track. **(1 mark)**
5. Read the information in the box How a refrigerator works.
   (a) Use the words in **bold** to label the diagram of the refrigerator below. **(2 marks)**



(b) Use the information in the box How a refrigerator works **construct** a flow chart that describes the changes of state that take place during the refrigeration process. Colour each state a different colour. For example, when the refrigerant is in the liquid state, you may choose to colour the relevant section blue. The flow chart has been started for you. **(4 marks)**



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Complete this digital doc: Worksheet 3.8: States of matter puzzles (doc-12367)

Complete this digital doc: Worksheet 3.9: States of matter summary (doc-12368)

TOPIC 4
Classification

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.

4.1.1 Why learn this?

A butterfly fluttering from one flower to the next on a bright summer day. Nothing could seem more peaceful. However, this sight may lead a biologist to ponder: How do we know it is a butterfly rather than a moth or another type of insect altogether? What type of butterfly is it? Is it a monarch butterfly, a viceroy butterfly, Milbert tortoiseshell or another species? How can we tell?

Classification provides answers to these questions and many others. It organises the great variety of life forms found on Earth into groups. This is also an important first step towards conservation.

LEARNING SEQUENCE

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Which features are used to classify a butterfly?



Thinking about classification

Classifying means putting things into groups. You classify things all the time. For example, when you organise your school bag, you are classifying things:

- Which types of items do you put in your pencil case?
- Which items go in your sports bag?
- What goes in your wallet?
- What do you store in your lunch box?
- Do you use particular parts of your school bag to store certain items?

1. Imagine that the contents of all the bags you take to school were tipped onto the floor. Write down some rules that would help your friends decide what to put where in your school bag; for example, all the things you can use to write go in the pencil case.
2. Different species of butterflies are shown below. Work with a partner. Organise the butterflies first into two groups, then into three groups. Present your answer in the form of a table.
3. Compare your answer with the students next to you. Did you use the same criteria to classify the butterflies?
4. Empty out the contents of your pencil case on the desk. Organise the objects from your pencil case into two groups, then three groups and then four groups. Each time, present your answer in a table, selecting the column headings carefully.
5. Butterflies are living things. What features do living things have in common?
6. Butterflies are also animals, invertebrates, arthropods and insects. Which classification groups do humans belong to?

Nine butterfly species



4.2 Why classify?

Science as a human endeavour

4.2.1 Classification brings order and organisation

Classifying means sorting items into groups. It is something humans do from a very young age. Toddlers sort their toys and classify humans as male or female, adult or child. In your wardrobe your clothes are probably classified in some way: socks in the drawer, jeans and t-shirts folded on the shelf and uniforms on hangers. Classifying is a way of organising and bringing order. Similarly, biologists organise living things into groups. This makes it easier for them to communicate and learn about particular organisms and how they are related to other living things. It is also the first step towards conserving the great diversity of organisms that inhabit our planet.

Classifying things into groups makes them easier to remember, describe and identify. For example, if you went to a supermarket to buy cornflakes, it would take you ages if the products in the supermarket were not classified into groups. Because cornflakes are classified as a breakfast cereal, you know where to look.

Scientific curiosity has resulted in the discovery of an increasing number of living things. This has led to an increased need to classify living things into groups. If you were to find an unknown organism, you could describe it on the basis of the sorts of features it shares with members of a particular group. However, it is not always easy to decide which group an organism fits into. For example, a French poodle looks very different from a sheepdog, but they are both dogs. A wolf looks very much like a dog, yet it is not a dog.

4.2.2 Early taxonomists — bringing order to chaos

A taxonomist is a biologist who specialises in classification. The work of early taxonomists including Joseph P de Tournefort (1656–1708), John Ray (1627–1705) and Carl Linnaeus (1707–1778) consisted of carefully observing living things, naming them and organising them into groups based on observable structures. Each of the above taxonomists produced books containing diagrams and descriptions of organisms. Tournefort and Ray focused on plant classification. Classification schemes were based on features such as the type of flower or seed, or whether the plant was a herb, shrub or tree.

In the 1700s, Carl Linnaeus designed a system of classification that had a huge impact on biology. He proposed that there were three main groups of living things. He called these kingdoms. The three kingdoms were divided into classes, and classes were in turn divided into orders, families, genera and species. While we now recognise that there are more than three kingdoms of life, and additional levels have been added, many of the ideas presented by Linnaeus are still used today. In our modern classification system there are seven main levels: kingdom, phylum, class, order, family, genus and species. This can be remembered with the mnemonic **King Phi**l **class**ed **ord**inary **famil**ies as **gen**erous and **speci**al. Two examples are given in the diagram below, which shows the full classification for the domestic cat and the type of tomatoes used in salads.

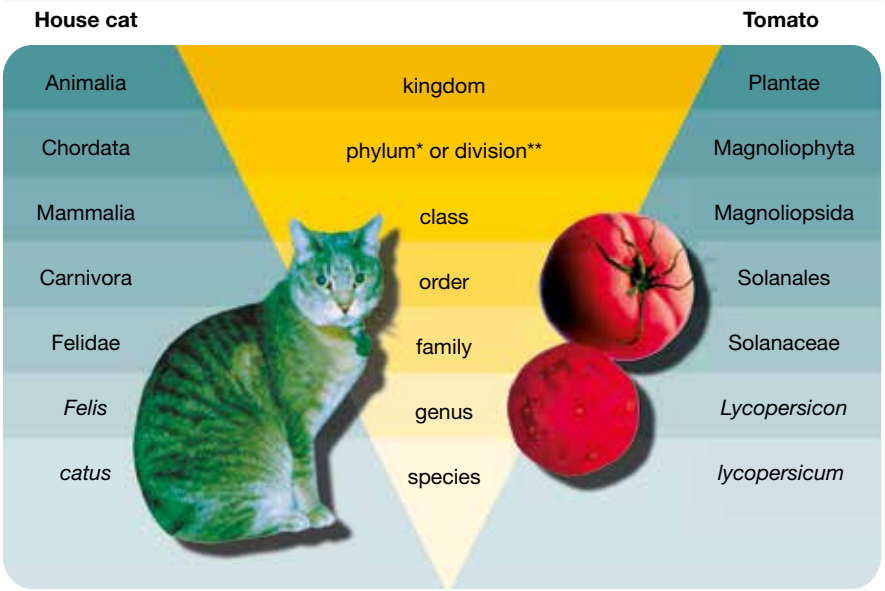
Linnaeus made another great contribution to taxonomy; he devised a system for naming all organisms. According to his system, each species has a unique name consisting of two parts: the genus and another name. The two-part name is underlined if it is handwritten, or written in italics if typed. The first part of the name has an initial capital letter, but the second name is all lower case. So the correct way of writing the species name for the common red kangaroo is *Macropus rufus*. It is closely related to the eastern grey kangaroo (*Macropus giganteus*) and the western grey kangaroo (*Macropus fuliginosus*), which, as their names indicate, all belong to the genus *Macropus*.

4.2.3 Improving communication

The names given to species by Linnaeus were Latin, because that was the language used by scientists at the time. Today's biologists do not always use Latin names but, importantly, the scientific name chosen for a species is used throughout the world, regardless of the language used by the scientists. So *Felis*

catus is the scientific name for the domestic cat in Spain, France, Italy and Australia, despite these countries having different national languages. Also, the fungus *Spongiforma squarepantsii* (see *How about that!* below) has the same name in the USA and Germany. This has made communication between biologists who speak different languages easier because there can be no confusion relating to species having different names in different languages.

How living things are classified, using the Linnaean system



* 'Phylum' for Kingdom Animalia
** 'Division' for Kingdom Plantae

There are other ways that classification makes communication more efficient. Organisms are classified into groups according to their features. Classifying an animal as a mammal indicates that it is covered in hair or fur and feeds its young milk. So, if a zoologist writes a paper about a newly discovered mammal species, we know immediately that it has these features.

HOW ABOUT THAT!

Carl Linnaeus's real name was actually Carl von Linné. He was Swedish, but in the early 1700s the language of science was Latin, so he used a latinised version of his name. His books were written in Latin. Today, scientists publish their research in various languages. English is the most commonly used language.

4.2.4 Classification and relationships

Organisms that belong to the same kingdom are more similar to each other than to organisms that belong to a different kingdom. Cows, dogs, lizards and fruit flies all belong to the animal kingdom, but banana plants belong to the plant kingdom. Cows, dogs, lizards and fruit flies are more similar to each other than to banana plants. In turn, cows, dogs and lizards all belong to the vertebrate phylum and are thus more similar

HOW ABOUT THAT!

New species are still being discovered today. Tim Flannery is an Australian scientist and conservationist. He has discovered and named more than 30 species of mammals, including the critically endangered blue-eyed spotted cuscus (*Spilocuscus wilsoni*) of Indonesia and a type of tree kangaroo in Irian Jaya that he named *Dendrolagus mbaiso*. How do biologists choose a name for a species? The tree kangaroo discovered by Flannery is named mbaiso in the local dialect (which means 'forbidden') in reference to the fact that it is believed to be sacred and is thus not hunted. Sometimes scientists name a species after a colleague or friend. Flannery named a long-beaked echidna species *Zaglossus attenboroughi* after Sir David Attenborough, the wildlife documentary producer and

A species of tree kangaroo discovered by Tim Flannery



presenter, whom he greatly admires. In some instances the name chosen for a species reflects the researcher's sense of humour. When a team of researchers from San Francisco State University discovered a new species of fungus in Borneo that looked like a sea sponge, they decided to name it *Spongiforma squarepantsii* after the cartoon character SpongeBob SquarePants.

Spongiforma squarepantsii



to each other than to fruit flies, which belong to the arthropod phylum. Cows and dogs both belong to the mammal class and are thus more similar to each other than to lizards, which belong to the reptile class.

We now understand that all the species living on Earth today have evolved over time. So species that are in the same groups are not only similar, but also shared a common ancestor more recently than species that do not belong to the same groups. In fact, changes are made to the classification of organisms regularly. Usually this is the result of new evidence that shows that certain groups of organisms are more closely related than once thought.

4.2.5 The first step towards conservation

Classifying organisms and naming newly discovered species is the first step towards conservation. Biodiversity is a measure of the variety of living things in a particular environment. In a tropical rainforest or a coral reef there is a great deal of biodiversity. Many different kinds of organisms live there. In contrast, a pine plantation has little biodiversity. An important goal of conservationists is to maintain biodiversity. Identifying the species living in an environment is the first step towards conserving the variety of species. Many taxonomists carry out field work that involves travelling the globe to observe, collect specimens and take photographs of the animals and plants in remote areas.

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** three reasons why biologists classify living things.
2. List the levels of classification in order from the highest to the lowest levels.
3. A species name is made up of two words. What do these words indicate?
4. **Define** the term 'biodiversity'.

Think

5. **Explain** why giving each species a unique scientific name that is the same in all countries makes communication easier between scientists.
6. A mnemonic is a trick that can be used to remember a list of words. For example, the following mnemonic can be used to remember the levels of classification: Create another mnemonic to remember the levels of classification. You could use just the first letter of each level rather than the first syllable.

King	Kingdom
Phil	Phylum
Classed	Class
Ordinary	Order
Families as	Family
Generous and	Genus
Special	Species

7. The full classification for humans is shown below.
   (a) Which group contains more living things, the kingdom 'animal' or the order 'primate'?
   (b) Dogs belong to the animal kingdom; they are vertebrates and they are also mammals. Use the table below to list some characteristics that dogs and humans have in common.
   (c) Chimpanzees and humans are closely related. Which of the groups listed in the table below do chimps belong to?

Category	Group	What all the living things in the group have in common
Kingdom	Animal	Made up of more than one cell; eats food
Phylum	Vertebrate	Backbone
Class	Mammal	Hair or fur; feeds its young milk
Order	Primate	Opposable thumb; nails instead of claws; binocular vision
Family	Homidae	Arms shorter than legs; nails flattened; upright stance
Genus	*Homo*	Walks upright on feet only; cares for young for a long time
Species	*sapiens*	Large brain; can talk and think abstractly; complex social structures

8. **Explain** why identifying and classifying the species in a particular environment is the first step towards conservation.
9. Use the **Scientific names** weblink in the Resources tab to tabulate the common and scientific names of any five mammals. Ensure you use the correct format for the scientific names.
10. Research one of the following taxonomists: Joseph de Tournefort, John Ray, Carl Linnaeus. Use the **FakeBook** weblink in the Resources tab to create a 'Facebook' page for the taxonomist you researched. Ensure that the page provides information about the taxonomist's scientific achievements.
11. Use the **World Wide Fund for Nature** weblink in the Resources tab and click on the 'Our work' tab to find out about some of the work carried out by the WWF. Write a paragraph to **explain** what the organisation is about and what they do.

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- **Explore more with this weblink:** Scientific names
- **Explore more with this weblink:** FakeBook
- **Explore more with this weblink:** World Wide Fund for Nature

4.3 Is it alive?

4.3.1 Alive or not alive?

Before we can start to classify living things, we need to find out what living things actually are. What features make something a living organism?

Trees are living things but rocks are not. What about a piece of bark that has fallen from the tree, or some lichen growing on the rock? Are they living things? To find out, we need to consider the following characteristics.

Jellyfish can propel themselves through the water.



4.3.2 Move

Many living things move independently. That means that they can move without having something pushing or pulling them. Animals move in many different ways. Some walk or run, some swim and some fly. The movement of plants is less obvious.

Certain plants can open and close their flowers; others such as sunflowers turn towards the sun. Movement is not an essential feature of living things. Some living things such as lichen and some bacteria cannot move independently.

Screaming is one way to respond to something frightening.



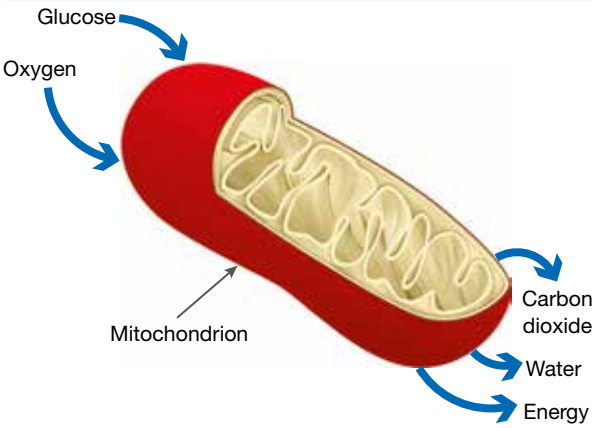
4.3.3 Respond

All living things respond to changes in their environment. Humans shiver if it is cold and run away if they can see danger ahead. Kangaroos lie in the shade on hot days and lick their forearms to keep cool. Plants grow towards light and close the pores in their leaves when it is hot.

4.3.4 Respire

All living things need energy to survive. Most living things get their energy from a process called **respiration**. This is a chemical reaction where glucose reacts with oxygen to form carbon dioxide and water. Energy is released in the process. Animals get the glucose they need for respiration from the food they eat. Plants make glucose using a process called **photosynthesis**.

Respiration



4.3.5 Assimilate

Living things **assimilate** (take in and process) substances. Animals assimilate food. They eat food, which is then broken down inside their bodies. Chemicals from the food, such as glucose, amino acids and vitamins, are used for various processes inside the body. Plants do not eat food. When they **photosynthesise**, they can make their own food using sunlight. However, plants do assimilate some substances, including water and minerals from the soil and carbon dioxide from the air.

Animals assimilate food.



4.3.6 Grow

Organisms grow and develop as they age. Some living things grow throughout their whole life. Humans, elephants and other animals grow until they reach a certain height, and then they stop growing.

As they get older, organisms may change in ways other than just increasing in size. Tadpoles lose their tails and grow legs as they turn into frogs. Caterpillars become butterflies, and male lions grow a mane as they reach adulthood.

Humans grow rapidly in their first year of life.



4.3.7 Excrete

Organisms produce and **excrete** (get rid of) waste. Humans breathe out carbon dioxide, which is a waste product of respiration, and urine. Urine contains a number of substances including waste products resulting from the breakdown of proteins. We also excrete water and salts in the form of sweat.

Just like animals, plants respire throughout the day and night. During the day, plants also photosynthesise. This process uses carbon dioxide and releases oxygen. So, during the day, plants actually excrete oxygen.

Dogs excrete some waste products in their urine.



4.3.8 Reproduce

All living things reproduce. They can make copies of themselves. Bacteria and other single-celled organisms reproduce by dividing into two. In some cases, two organisms (a male and a female) are needed for reproduction. The male and female both produce sex cells, which need to combine to produce a new living thing. The sex cells of mammals are called eggs and sperm. They combine to start a new life. Plants can reproduce in a number of ways. Some plants produce seeds as part of their reproductive cycle.

When animals have babies, they are reproducing.



4.3.9 Is it non-living or dead?

Something that is dead was once living. At some stage, it had all the features of living things but it has now stopped living. A squashed fly, the plant you forgot to water and the egg you had for breakfast are all dead. Non-living things do not have and never have had all the characteristics of living things. A robot, a car and a stereo may have some of the features of living things but they lack important features such as the ability to reproduce. They are non-living.

HOW ABOUT THAT!

Hiroshi Ishiguro has designed robots that are so life like they are often confused for humans. He teaches at a university in Japan. The university is one hour away from his home. Ishiguro has made a robot that looks just like him. He has used the robot to give some of his lectures from the comfort of his own home. Ishiguro can control the robot remotely from home and have his own voice come out of the robot's mouth. It usually takes a little while for his students to work out whether they are being taught by a real person or his robot look-alike. The robot is so like a human that many people find themselves apologising to the robot if they stare at it for a little too long.

Hiroshi Ishiguro and his robot twin



INVESTIGATION 4.1

Living, non-living or dead

AIM: To classify things as living, non-living or dead

- Copy and complete the table below.

Characteristics	 Robo-bilby (electronic toy)	 Bilby	 Bilby fossil
Can move			
Responds to changes in its environment			
Respires (uses oxygen to process glucose and release energy)			
Assimilates (takes in) substances such as food and water			
Grows and develops as it gets older			
Produces and excretes waste			
Reproduces itself			

- Construct another table the same as the one above but replace the bilbies with:
  (a) paper
  (b) fire
  (c) a tree.
- Complete the table.

Discussion

1. Which of the three bilbies is non-living? Which characteristics does it have?
2. Which of the three bilbies is dead? Which characteristics does it have?
3. Which of the paper, fire and tree is non-living?
4. Does the living thing have all of the characteristics listed?
5. Which characteristics does the living thing have that the non-living thing does not?

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. Match each of the words in column 1 with its correct meaning from column 2.
2. Imagine that a funnel-web spider walked across your desk right now. **Outline** three ways in which your body would respond.
3. Most living things need oxygen to survive. **Explain** why.

Word	Meaning
(a) Respire	A Make more copies of itself
(b) Grow	B React to a change in the environment
(c) Assimilate	C Get bigger
(d) Reproduce	D Take in and process substances
(e) Move independently	E Get rid of waste
(f) Respond	F Get energy, usually by a chemical reaction between glucose and oxygen
(g) Excrete	G Change position from one place to another without being pushed or pulled

4. The words ‘respiration’ and ‘breathing’ are often confused. **Explain** the difference between these two terms.
5. **Outline** how each of the following reproduces.
   (a) Magpie
   (b) Eucalyptus tree
   (c) Bacteria
6. **Recall** three waste products that humans excrete.
7. **Distinguish** between dead things and non-living things.

Think and discuss

8. If we put together the first letters of the characteristics of living things (move, respond, respire, assimilate, grow, excrete, reproduce), they spell ‘Mr Rager’. Think of another way to remember the characteristics of living things. For example, you might find a sentence where each word starts with the first letter of one of the characteristics of living things.
9. Use Venn diagrams or double bubble maps to **compare** and **contrast** the features of living, non-living and dead things. Compare only two things at a time.
10. (a) **Classify** each of the items shown in the drawings opposite as living, non-living or dead. Present your answer as a table.
    (b) Which of the things were difficult to classify? Why?
    (c) For the items you classified as non-living or dead, list the characteristics of living things they do not display.
11. Non-living things often have some, but not all, of the features of living things. **Identify** the features of living things that the following share.
    (a) Hot-air balloon
    (b) Television set
12. Robots are becoming increasingly life like. Use the **Asimo robot** weblinks in the Resources tab to find out about the Asimo robot and the androids designed by Hiroshi Ishiguro.
    (a) In what ways are these robots like living things? In what ways are they different?
    (b) What can the Asimo robot do? How could robots such as Asimo be used to help humans in the future?
    (c) Which features make the androids designed by Hiroshi Ishiguro so life like?
13. Test your understanding of the term ‘living’ by using the **Living or non-living quiz** weblink in the Resources tab.

Living, non-living or dead?



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Complete this digital doc: Worksheet 4.1: Is it alive? (doc-12369)

Complete this digital doc: Worksheet 4.2: Creatures from a parallel universe (doc-12370)

Complete this digital doc: Worksheet 4.3: Responding (doc-12371)

Explore more with this weblink: Asimo robot 1

Explore more with this weblink: Asimo robot 2

Explore more with this weblink: Living or non-living quiz

4.4 Identification keys

4.4.1 Dichotomous keys

Once the features of an organism have been noted, the information can be used to identify it using identification keys.

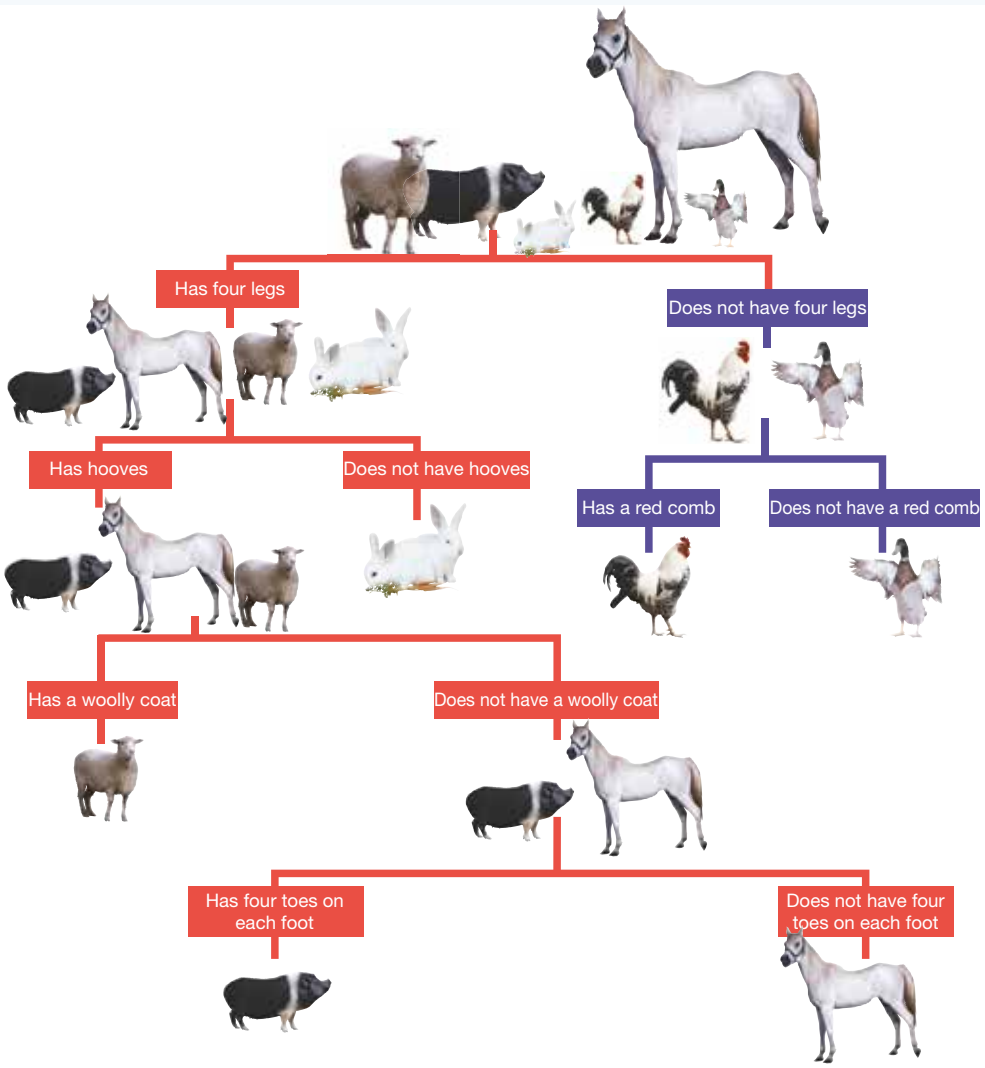
The information that is used to classify organisms is sometimes put into a key. The key shown below is called a **dichotomous key**, because there are only *two* choices at each branch (dichotomous = 'cutting in two'). It shows how some farm animals may be divided on the basis of similarities and differences in their features.

Features such as size, colour, behaviour and habitat are not good for classification because they can change throughout the life of the organism. Using the structure of an organism is much better.

4.4.2 Branching keys

The dichotomous key opposite is a branching key. Such keys are quite easy to create but, if there are many organisms to classify, they take up a lot of space. Another way of presenting a dichotomous key is in tabular format. To change a branching key into a tabular key, you just need to give each fork of the dichotomous key a number. This number becomes the step number in your tabular key. The diagrams opposite show the same key presented below as a branching key and a tabular key.

In a dichotomous key, you always select from two choices. In this key, you decide whether an organism has a particular feature.



INVESTIGATION 4.2

Making a class key

AIM: To classify members of your class

You will need:

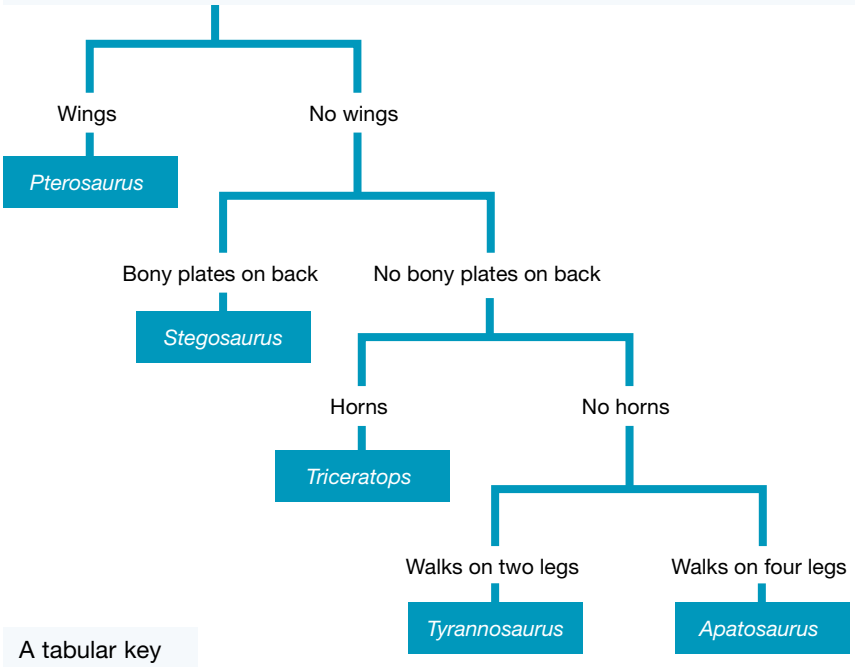
tape measures or string and rulers

- Measure, observe and record at least 10 different characteristics for each member of the class. You may like to include some of the following:
  wrist size (cm)
  distance from elbow to shoulder (cm)
  foot length (cm)
  height (cm)
  eye colour
  hair colour
  wears watch
  pierced ears
- Have each member of the class select a secret code name.
- Use some of these recorded class characteristics to construct a key (tree map or dichotomous key) that will separate as many individuals (using their code names) as possible. (*Hint:* You may find it best to describe measurements as 'greater than' or 'less than' a particular measurement.)
- Have someone from outside the class use the key to find the identity of one of the class members.

Discussion

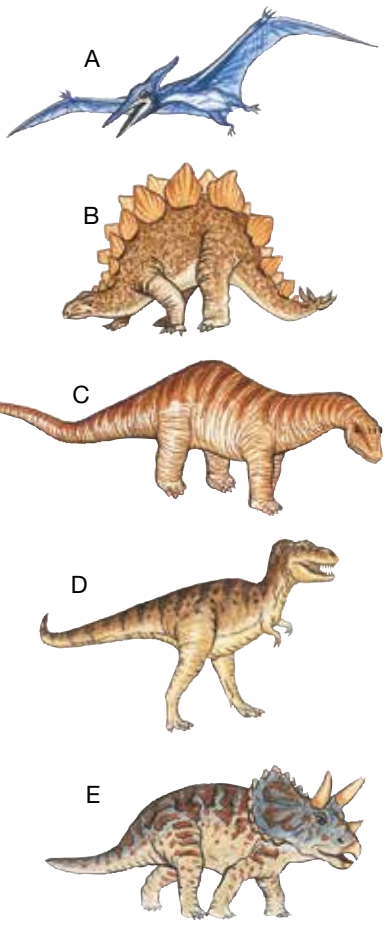
1. How successful was your key?
2. If you were to do the activity again, what would you do differently to improve its success?
3. Were some characteristics of more use than others? Explain.

A branching key



A tabular key

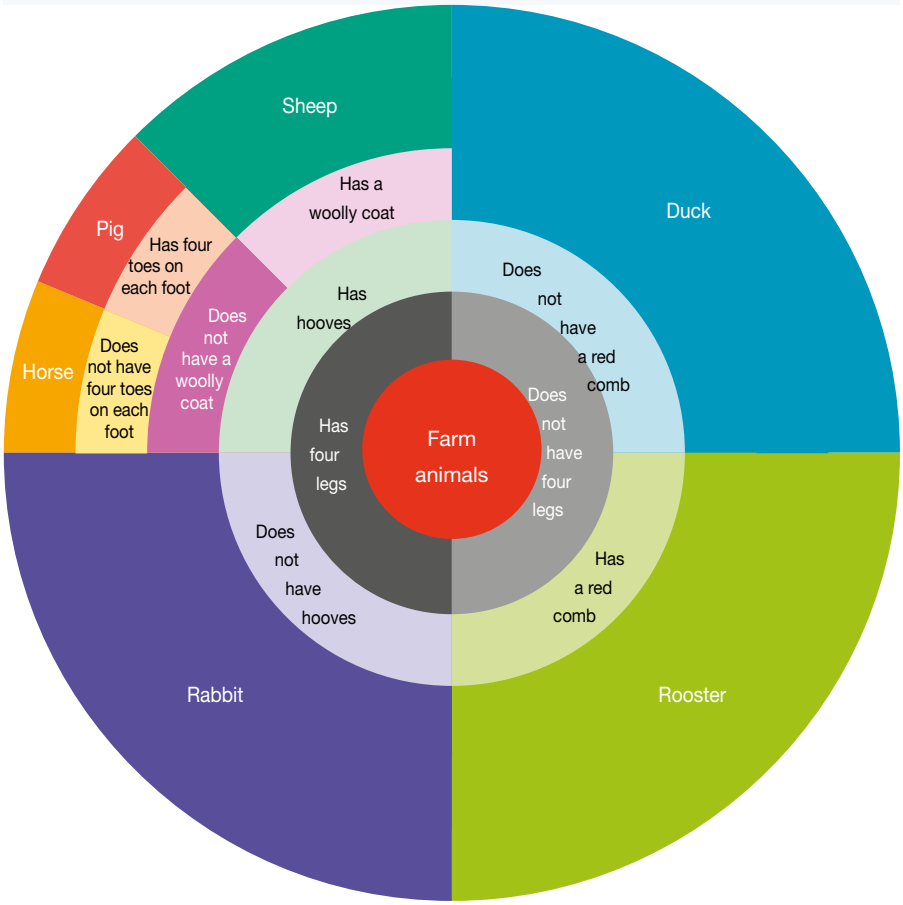
1. Wings ..... *Pterosaurus*
   No wings ..... Go to 2
2. Bony plates on back ..... *Stegosaurus*
   No bony plates on back ..... Go to 3
3. Horns ..... *Triceratops*
   No horns ..... Go to 4
4. Walks on two legs ..... *Tyrannosaurus*
   Walks on four legs ..... *Apatosaurus*



4.4.3 Circular keys

The diagram below shows another type of key — a circular key. To read circular keys you start in the centre of the circle. As you move outwards from the centre you choose one of the options in each layer until you reach the outer layer. The circular key below shows the same information as the branching key on page 132. Which is easier to use? Which is easier to construct?

A circular key



4.4 Exercise: Remember and think

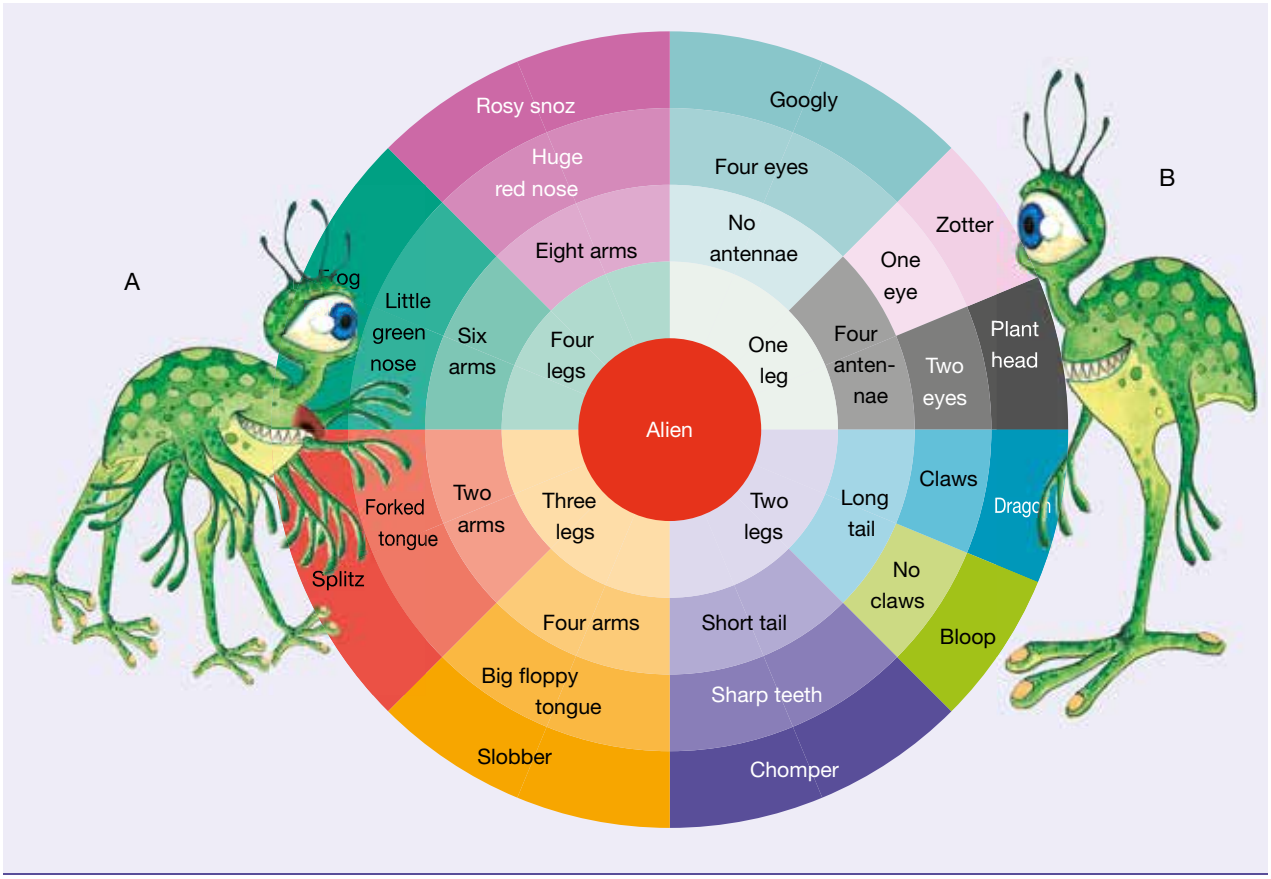
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Recall** what a dichotomous key is used for. Why is it called dichotomous?
2. **Propose** why keys are sometimes presented in tabular rather than branching format.

Think and discuss

3. Use the key on page 133 to **classify** the dinosaurs labelled A, B, C, D and E.
4. Imagine that you have landed on another planet. Weird creatures live there. You noted the characteristics of some that you saw and prepared the circular key shown below. Use it to help you **classify** the creatures A and B you have just found, shown here.
5. **Construct** a tabular key using the branching key shown on page 133.
6. Collect a leaf from each of eight different plants in the school grounds.
   (a) On an A3 sheet of paper, create a branching dichotomous key to **classify** the leaves.
   (b) **Construct** the key in your exercise book as a tabular key.



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Complete this digital doc: Worksheet 4.4: Branching keys (doc-12372)

Complete this digital doc: Worksheet 4.5: Tabular keys (doc-12373)

4.5 Classifying small living things

In the 1700s Carl Linnaeus proposed a system of classification that grouped all living things into three kingdoms. The invention of the microscope led to the discovery of organisms that did not fit into any of these groups, and two new kingdoms have since been created. More recent advances in technology have provided new information about unicellular organisms. As a result it has been proposed that a five-kingdom system of classification was no longer adequate and a new classification scheme has been suggested to replace it.

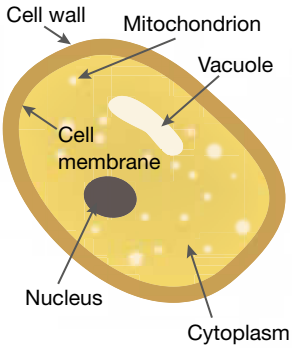
4.5.1 Animal or plant?

To early biologists, living things belonged to one of two groups: animal or plant. Animals needed to eat food and plants did not. Most animals could move about and catch their food. Most plants were green and did not move about. Eventually biologists came across living things that did not fit into these two groups. Fungi, including mushrooms and moulds, are not green so they cannot make their own food. However, they do not catch and eat food; instead they produce chemicals that digest the material on which they grow and the nutrients released are absorbed by the fungus. A new kingdom, Fungi, had to be created to accommodate these organisms.

4.5.2 The microscope provides further information

The invention of the microscope allowed scientists to see the cells of animals, plants and fungi, and it became obvious that there were important differences between them at the cellular level. In topic 2 you saw that plant cells have structures that are not found in animal cells: a rigid cellulose cell wall on the outside of the cell, a large water-filled vacuole, and chloroplasts where photosynthesis takes place. Most fungal cells also have a cell wall, although it is not made of cellulose. Instead it is made of chitin and other complex sugars; chitin is the substance that is found in the exoskeleton (the tough, crunchy outer layer) of insects and arthropods. Fungal cells contain one or more large vacuoles, but they do not have chloroplasts as they do not carry out photosynthesis.

A typical cell of a fungus



The microscope also made it possible for microscopic living things to be seen, including unicellular organisms. Unicellular organisms are made up of just one cell. As more information was discovered about unicellular organisms, two additional kingdoms were added to accommodate these: Kingdom Protista, consisting of unicellular organisms that possess a true nucleus, and Kingdom Monera, which includes unicellular organisms that lack a true nucleus. The protists include *Amoeba*, *Euglena* and *Paramecium* (see Section 2.7 on page 68 to find out more about these). Bacteria and cyanobacteria belong to Kingdom Monera. There were thus five kingdoms — Animalia, Plantae, Fungi, Protista and Monera — as illustrated in the diagram below.

In 1977 Carl Woese, a molecular biologist, published research findings that suggested that the five-kingdom classification system was inadequate. His research involved comparing the structure of a chemical called RNA in cells from different organisms. You have probably heard of DNA. RNA is similar to DNA. Species that are closely related have very similar RNA, whereas distantly related species have many differences in their RNA. He found that there were certain bacteria-like organisms whose RNA was actually more similar to that of animals and plants than to other bacteria. This group is now called the Archaea. They are found in extreme environments such as hot springs, very salty or acidic pools and in places where oxygen is not available. It is believed that they are similar to the earliest life forms to have existed on Earth. Woese proposed a new classification system. Instead of five kingdoms he suggested that there should be three domains: Archaea, Bacteria (true bacteria) and Eukarya (all the living things made up of one or more cells with a nucleus). These three domains are then divided into kingdoms, so that the plant, animal, fungi and protists all belong to the Eukarya domain.

The five kingdoms

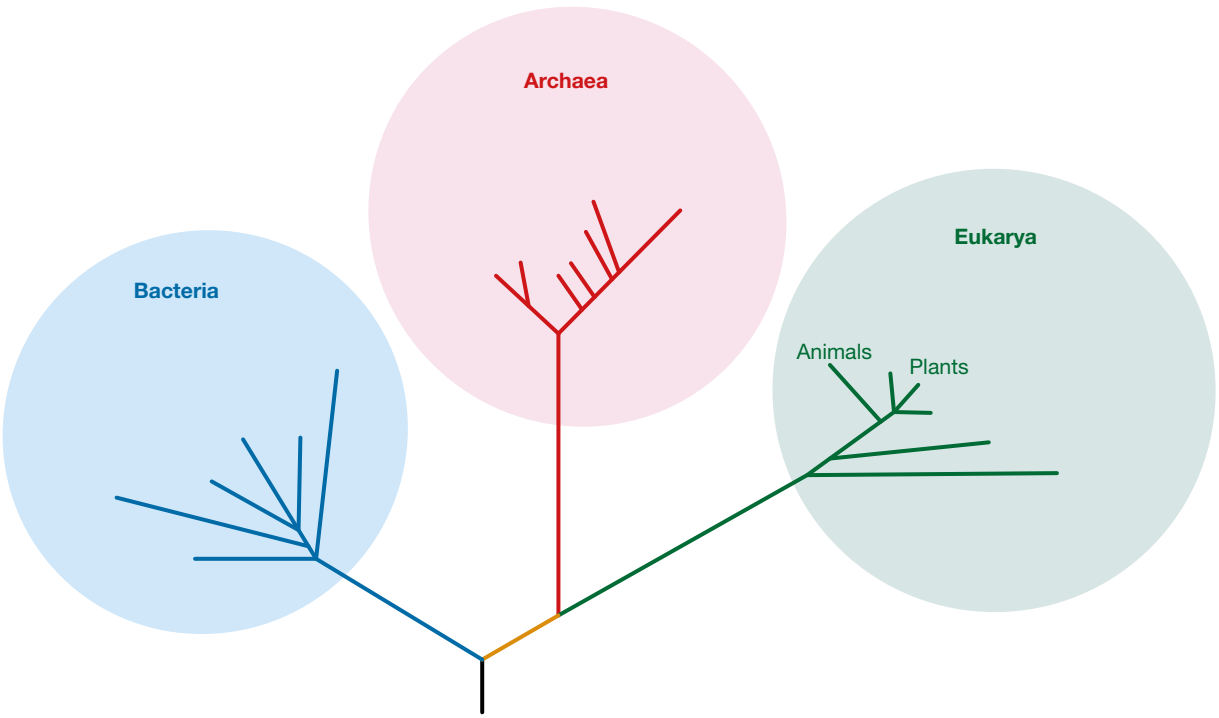


4.5.3 Main features of the five kingdoms

Main features of the five kingdoms

Kingdom	Animalia	Plantae	Fungi	Protista	Monera
Unicellular or multicellular?	Multicellular	Multicellular	Most multicellular; some unicellular	Unicellular	Unicellular
Cell wall	No cell wall	Cellulose cell wall	Predominantly chitin	Many have no cell wall; some have a cell wall	Cell wall present; composition varies
True nucleus	Present	Present	Present	Present	Absent
Mode of nutrition	Eat or absorb other organisms	Photosynthesise to produce sugars	Produce chemicals that break down the material on which they grow and absorb the nutrients released	Some photosynthesise; some ingest food	Some absorb nutrients from surroundings; some photosynthesise; some use other chemical processes
Chloroplasts	Absent	Present	Absent	Present in those that photosynthesise	Absent (those that photosynthesise have chlorophyll but no chloroplasts)
Examples	Pigeon, earthworm, ant, camel, human, starfish	Eucalyptus tree, grass, wheat, rose bush	Baker's yeast, mushrooms, bread mould	*Amoeba, Euglena, Paramecium*	*Escherichia coli, Staphylococcus aureus*

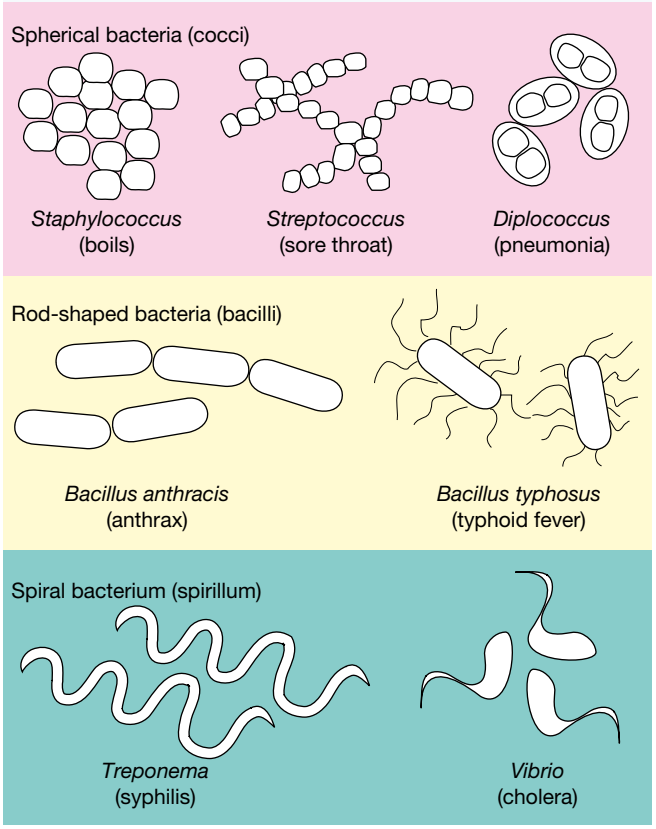
The three-domain classification scheme proposed by Woese



4.5.4 Classifying bacteria

Bacteria come in different shapes, and their names are often an indication of their shape and the way in which they clump together. Some bacteria are round (cocci) and some are rod shaped (bacilli). Some are spiral shaped (spirillum) and some are comma shaped (vibrio). The prefix *strepto-* is used to describe bacteria that form chains. *Streptococcus* consists of round cells that organise themselves in chains, whereas *Streptobacillus* consists of rod-shaped cells arranged in a chain. When bacteria are organised in pairs, the prefix *diplo-* is used. *Diplococcus* consists of two round bacterial cells inside a capsule. The prefix *staphylo-* indicates bacteria that clump together like a bunch of grapes.

Some types of disease-causing bacteria



INVESTIGATION 4.3

Classifying micro-organisms

AIM: To compare bacteria and protozoa

You will need:

microscope
prepared slides or live cultures of protozoa such as Paramecium, Euglena, Amoeba
prepared slide of bacteria
electron micrographs of bacteria and protozoa

- Observe the protozoa and the bacteria under the microscope. Draw diagrams of each type of organism or take photos using a digital eyepiece.
- Use the **Electron micrographs** weblink and compare the micrographs of the bacteria and protozoa.

Discussion

1. Compare the sizes of the protozoa and bacteria.
2. Which group of organisms (protozoa or bacteria) is more complex. Explain your answer.

HOW ABOUT THAT!

The fruit fly *Drosophila melanogaster* has been extensively studied by biologists, particularly those working in the field of genetics. It has been used in many breeding experiments to study how characteristics are inherited. To the great concern of many biologists, it is set to undergo a name change. The name *Drosophila melanogaster* indicates that this particular fruit fly belongs to the genus *Drosophila*. Comparison of the DNA of many species of fruit flies suggests that the fruit fly formerly known as *Drosophila melanogaster* actually belongs to the *Sophophora* genus. The fly will therefore be renamed *Sophophora melanogaster*. This is another example of how technological advances can change the classification of organisms.

The fruit fly *Sophophora melanogaster*, formerly known as *Drosophila melanogaster*



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. **Distinguish** between the following pairs of kingdoms.
   (a) Animals and plants
   (b) Plants and fungi
   (c) Fungi and animals
   (d) Protists and monerans
2. Use the diagrams in Section 2.5 on page 59 and this section to draw a labelled diagram of typical animal, plant and fungal cells.
3. **Outline** why Woese proposed a new classification scheme to replace the five-kingdom system.
4. **Identify** the three domains in Woese's classification system.
5. To which domains do animals, plants, fungi and protists belong?
6. The name *Drosophila melanogaster* indicates that the fruit fly belongs to the genus _____. Its name will be changed to _____ _____to indicate that it actually belongs to the _____ genus.
7. Match each word part on the left with one of the descriptions on the right.

Word part	Description
(a) Cocci	A Comma shaped
(b) Strepto	B Spiral shaped
(c) Staphylo	C Chain of bacterial cells
(d) Spirillum	D Round
(e) Diplo	E Bacterial cells organised in a clump like grapes
(f) Vibrio	F Rod shaped
(g) Bacillus	G Two bacterial cells enclosed by a capsule

Think

8. **Classify** the following organisms into their kingdoms: dog, whale, wattle tree, mould, grass, spider, ant, jellyfish, *E. coli*, clover, yeast, moss.
9. **Describe** the impact of the microscope on classification.
10. **Explain** why it is likely that classification schemes will continue to change over time.
11. Use the information in the diagram given on page 138 to answer the following questions.
    (a) **Distinguish** between *Staphylococcus* and *Streptococcus*.
    (b) **Distinguish** between *Vibrio* and *Bacillus anthracis*, which causes anthrax.
    (c) Create a dichotomous key to classify the bacteria shown in the diagram.

ICT

12. Search the internet to find more information (including pictures) about each of the five kingdoms. Use this information to **construct**, on a sheet of A3 paper, your own 'kingdom wheel' similar to that on page 136.
13. Use the **Inspiration** weblink in the Resources tab to download a trial copy of this visual thinking and learning software. Use the program to create a dichotomous key that can be used to sort organisms into the five kingdoms.
14. Test your ability to **classify** the world's living creatures by completing the **'Time Out': Kingdoms** interactivity in the Resources tab **(int-0204).**

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Complete this digital doc: Worksheet 4.6: Five-kingdom classification (doc-12374)

Explore more with this weblink: Inspiration

Try out this interactivity: 'Time Out': Kingdoms (int-0204)

4.6 Classification of animals using structural features

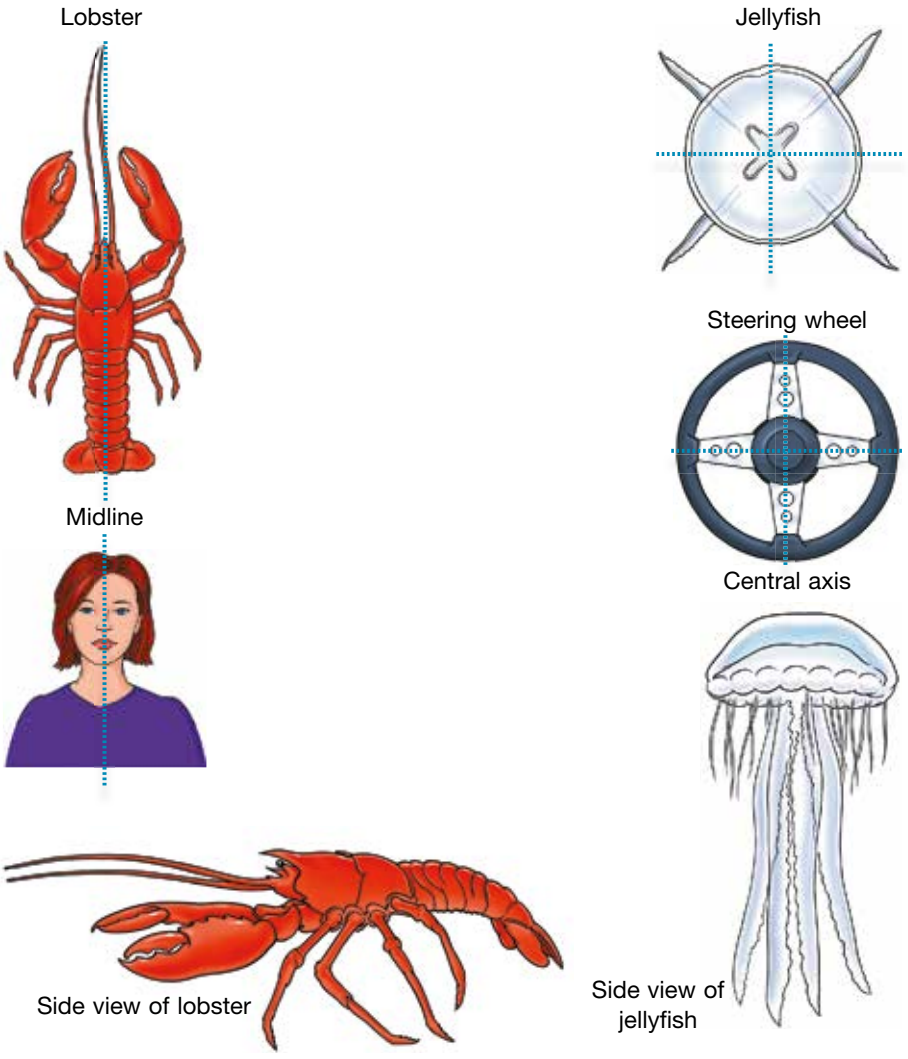
4.6.1 Some structural features used for classification

When biologists classify living things they use structural features as far as possible. These are features that relate to the way the organism is built. The key on the next page uses structural features to classify animals into eight phyla.

Symmetry

Some animals, including earthworms, humans and dogs have bilateral symmetry. Starfish and sea stars have radial symmetry. The diagram below illustrates what these terms mean.

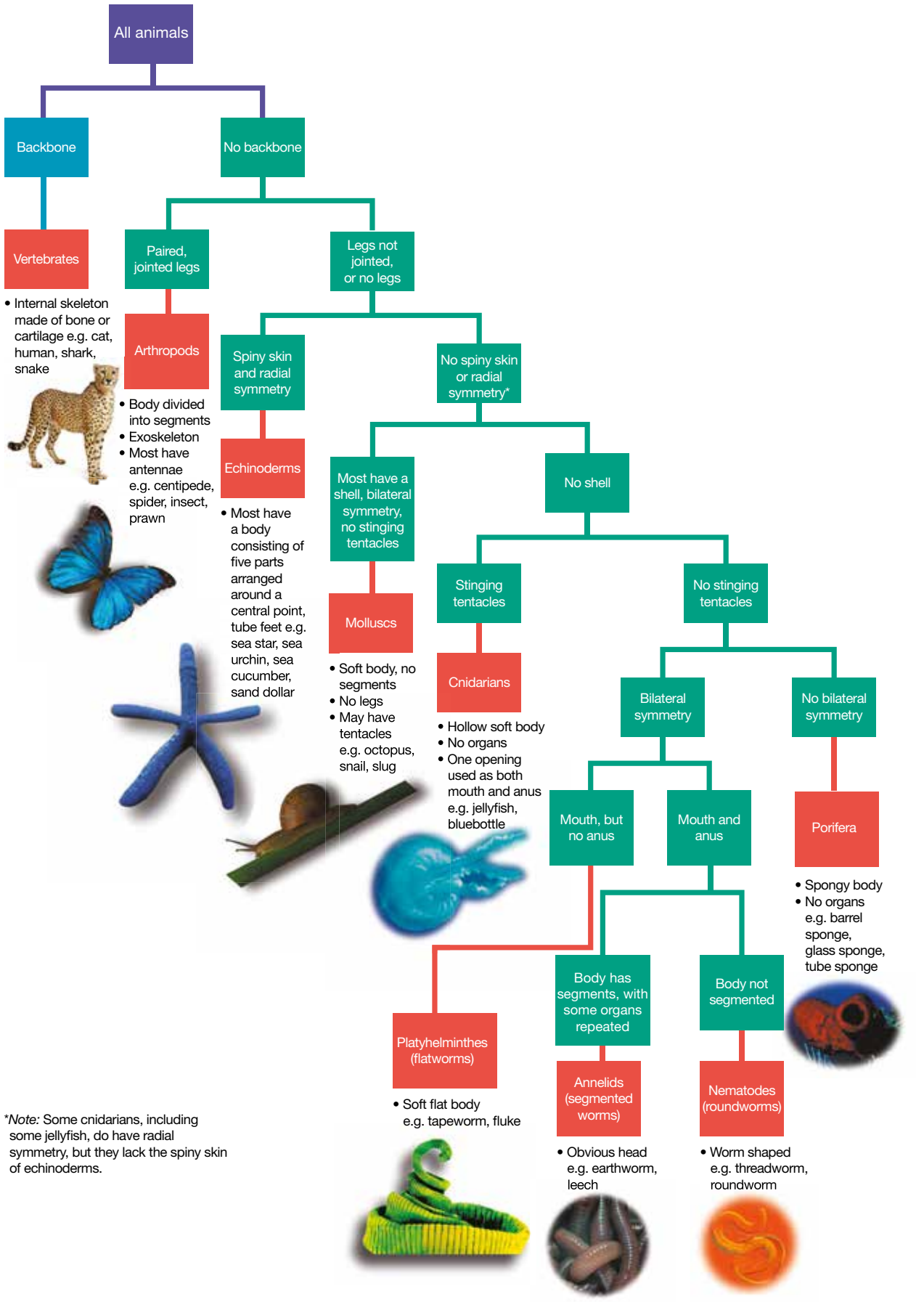
Symmetry in animals: bilateral symmetry (left) and radial symmetry (right)



4.6.2 Type of skeleton

Humans have a skeleton made of bone inside their bodies. Our muscles are attached to our bones. This is called an endoskeleton. Insects, spiders and prawns have a skeleton outside their bodies. Their muscles are attached to the crunchy outer coating that covers their bodies. This is called an exoskeleton.

Structural features can be used to classify animals into eight phyla.



Note: Some cnidarians, including some jellyfish, do have radial symmetry, but they lack the spiny skin of echinoderms.

4.6.3 Meet the arthropods

Arthropods are the most successful group of animals on the planet. Most arthropods are tiny, but they make up for their small size with their sheer numbers. There are far more arthropods on land than there are vertebrates or other groups of animals. They are found in the seas, in rivers and streams, on land and in the air. One group of particularly successful land arthropods are the insects. In addition to the features they share with the other arthropods — an exoskeleton, bilateral symmetry and jointed limbs — they also share a number of other characteristics. Insects have a body made up of three sections: head, thorax and abdomen. They have three pairs of legs and one pair of antennae (feelers). Most insects also have two pairs of wings, although the outer wings sometimes appear more like protective casings for the finer pair of wings hidden underneath.

INVESTIGATION 4.4

Classifying animals into phyla

AIM: To investigate characteristics used to classify animals

You will need:
preserved specimens or photos of animals from a range of phyla
hand lens

CAUTION: Some specimens are preserved in a liquid called formaldehyde. Formaldehyde is toxic and possibly carcinogenic. If you are provided with specimens in jars that contain liquid, do not open the jars. Look at the specimen through the sealed jar.

- Observe each specimen carefully. Use a hand lens if necessary.
- Use the key on page 141 to decide which phylum each animal belongs to.
- Draw up a results table with the following column headings:
  - Name of animal
  - Phylum
  - Characteristics used to classify.

Discussion

1. Were there any characteristics in the key that were difficult to identify in the specimens?
2. Which phyla were most difficult to distinguish? Why?

4.6 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. **Classify** the following as structural or non-structural features.
   (a) Two pairs of legs
   (b) Producing high-pitched whistle-like sounds
   (c) Spiny skin
   (d) Eight eyes
   (e) Caring for young for extended period of time
   (f) Circulatory system consisting of a heart and blood vessels
   (g) Excellent sense of smell
   (h) Very large nose
   (i) Running at speeds of up to 30 km/h
2. **Classify** the flowing objects as having radial or bilateral symmetry.
   (a) Armchair
   (b) Circular table
   (c) Star shape
   (d) Rectangle
   (e) Pen
   (f) Door knob

Think

3. **Explain** why it is best to use structural features rather than other features when classifying organisms.
4. Vertebrates make up only about 10 per cent of the animals on Earth, yet if you were asked to name 20 animals most of the animals in your list would probably be vertebrates. Suggest why we tend to know a great deal more about vertebrates than invertebrates.

Skill builder

5. In the key shown previously, **identify** the features used to distinguish between:
   (a) vertebrates and all the other phyla
   (b) echinoderms and molluscs
   (c) molluscs and cnidarians
   (d) porifera and cnidarians
   (e) the three different types of worm.
6. Use the key to **classify** the following organisms.
   (a) Oyster
   (b) Cockroach
   (c) Cow
   (d) Scorpion

Investigate

7. Find three more examples for each phylum in the key shown on page 141. Use a search engine to find photos of each.
8. The key on page 141 shows eight phyla. Find out if there are additional phyla and what their names are.
9. Use the **Howjsay** weblink in the Resources tab to find out the correct pronunciation of each of the phylum names shown in the key.

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Explore more with this weblink: Howjsay

4.7 Meet the vertebrates

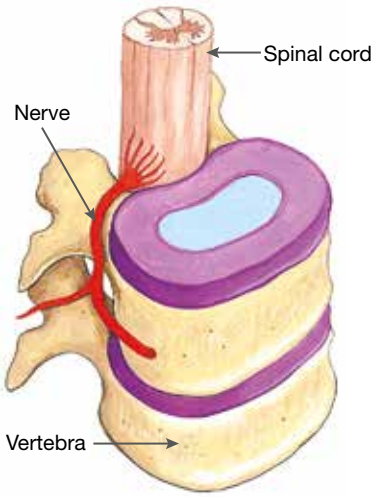
4.7.1 Vertebrates

There is one group of animals you probably know well – the vertebrates. Even though this group accounts for only about 10 per cent of all the animals found on Earth, they tend to make their presence obvious. Most of the largest animals on our planet are vertebrates.

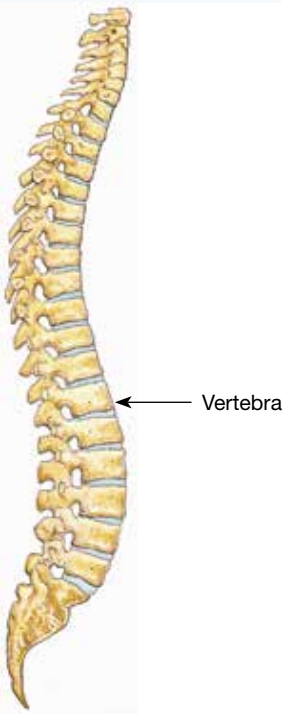
Vertebrates have the following characteristics:

- a rod in their back called a notochord. In developing animals (embryos), the notochord is made of cartilage. Cartilage is softer than bone. Your nose and ears are made of cartilage. As animals develop, the notochord is replaced by a hollow tube called the vertebral column. It is made up of parts called vertebrae. Vertebrae are usually made of bone but, in sharks and some other fish, they are made of cartilage.
- a nerve cord that runs through the middle of the vertebral column
- muscles attached to the vertebrae
- a brain protected by plates made of bone or cartilage (a skull)
- bones or cartilage in other parts of their bodies and muscles that are attached to these.

The spinal cord runs through the middle of the vertebral column.



The 'backbone' is not a single bone. It is made up of many small bones called vertebrae. The vertebrae are stacked on top of each other to form a hollow column called the vertebral column.



4.7.2 Vertebrate groups

Vertebrates can be divided up into five main groups: fish, amphibians, reptiles, birds and mammals. The fish group is actually made up of a number of classes including the bony fishes and the cartilaginous fishes (fish with a skeleton made of cartilage). Some important differences between the groups of vertebrates are their body covering, their mode of reproduction and whether they are endotherms or ectotherms. Reptiles and fish have scales covering their bodies, birds are covered in feathers, mammals have hair or fur, and amphibians have moist skin. Most vertebrates hatch out of eggs. Birds produce eggs with a hard shell. Reptile eggs have a leathery shell whereas amphibian and fish eggs lack a shell and dry out unless they are in water. Most mammals, except monotremes, do not hatch out of eggs. Mammals have another important difference — they feed their babies milk.

All vertebrates except mammals and birds are ectotherms. That means that they do not maintain a constant body temperature. Lizards are ectotherms. On cold mornings, their bodies are cold and the chemical reactions inside their bodies occur slowly. After lying in the sun, their bodies warm up. Humans are endotherms. Our body temperature remains at a steady temperature unless we are sick and have a fever.

HOW ABOUT THAT!

The group we call 'fish' is actually made up of three separate classes. When cooking fish you have probably encountered fish bones. Most of the fish we eat, including tuna, bass, flounder, barramundi and salmon, are bony fish. These fish have a jaw, their skin is covered with scales and their skeleton is made of bones. The scientific name for this group of fish is osteichthyes.

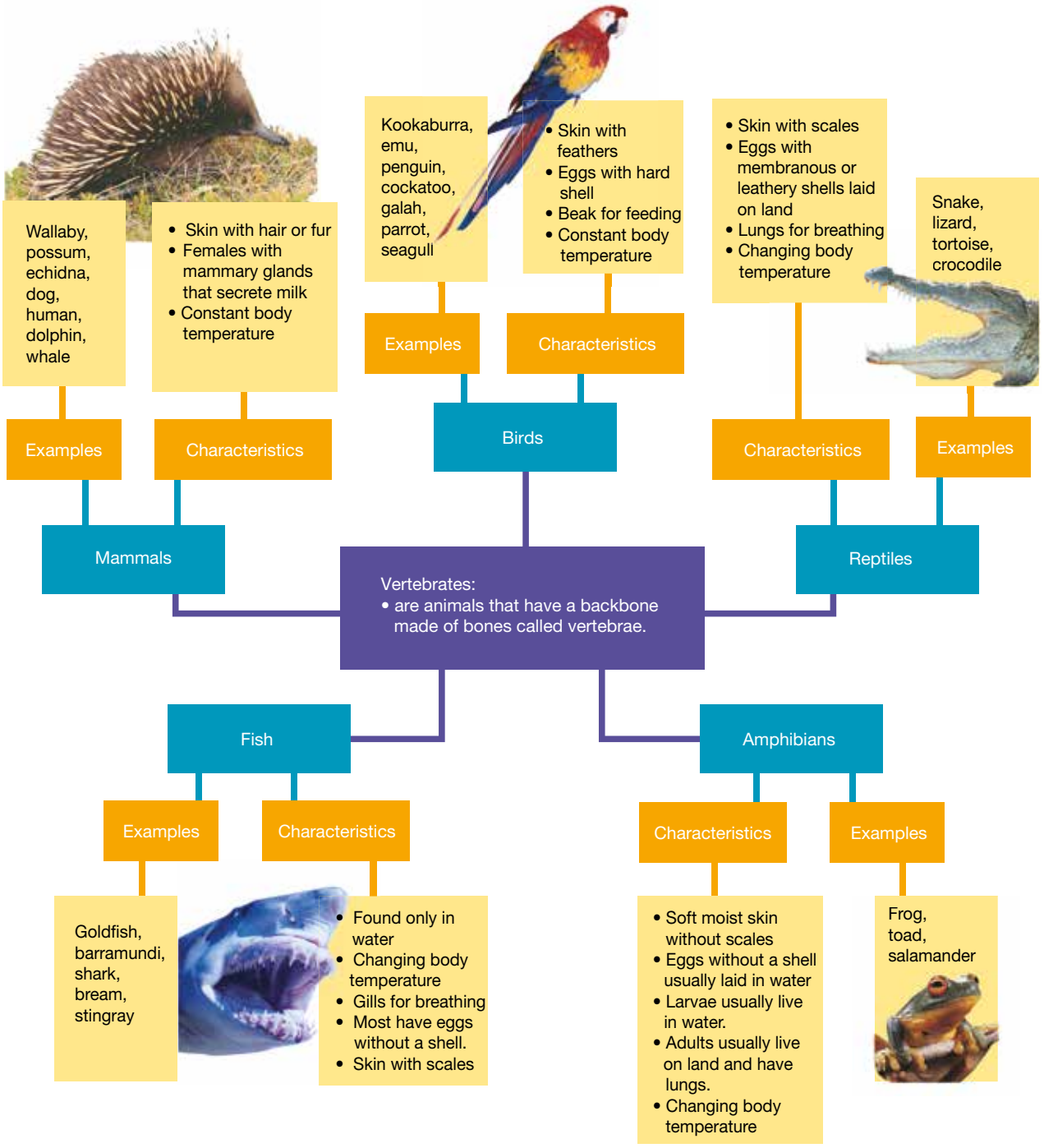
Another fish that is used in cooking is shark. In fact, the fish called 'flake' in fish shops and restaurants is shark. Sharks belong to a class called chondrichthyes. Their skin is covered with small tooth-like scales and thus feels rough. They have a jaw and their skeleton is made of cartilage. Cartilage is more flexible than bone. Your ears and the tip of your nose have cartilage rather than bone. Stingrays belong to the same class as sharks.

The third class of fish is agnatha, the jawless fish. These are believed to be most similar to the first fish to have evolved in the oceans. They lack jaws, do not have fins or true eyes but they do have a light-sensitive spot called the pineal eye.

Lamprey, a type of jawless fish



Vertebrates can be classified into five main groups: fish, amphibians, reptiles, birds and mammals.



4.7 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 'cartilage', 'vertebra', 'ectotherm' and 'endotherm'.
2. The following features are found in many vertebrates. The words have been scrambled. Unscramble the words and write them in your notebook under the heading 'Vertebrate features'.
   kllus, bainr, cdhnooort, cdeenorrv, abceellmnourrtv, celmus, benos

3. Which group of vertebrates do humans belong to? **Explain** why.
4. **Identify** the group of vertebrates that each of the following animals belongs to.
   (a) Snake (b) Cane toad (c) Goldfish
   (d) Whale (e) Emu (f) Shark
5. **Distinguish** between bony and cartilaginous fish, and give an example of each.
6. Copy and complete the table below.

Think

7. Who am I? **Identify** the vertebrate group that each of the following animals belongs to.
   (a) I have lungs but no legs. My offspring are found in membranous-shelled eggs and use lungs to breathe.
   (b) I have moist skin but no scales, and two pairs of legs. Although I have lungs and live on land, my young usually live in water and use gills to breathe.
   (c) I have a constant body temperature and feathers and lay eggs with a hard shell.
   (d) I have scales, I breathe using gills and I live in water.
8. Amphibians start their lives in water. For example, many frog species start as tadpoles living in ponds and streams. However, adult frogs breathe air using lungs and can travel some distance away from water. **Explain** why amphibians need to come back to the water to lay eggs.

	Fish	Amphibians	Reptiles	Birds	Mammals
Is body temperature constant or changing?					
What is the body covered with?					
Does it lay eggs? If so, what type of shell do the eggs have?					
Does it feed its young milk?					
Give three examples.					

9. In the table at right, match the English translations to the scientific names.

English translation	Scientific name
(a) Greek: living a double life	A Reptilia
(b) Latin: creeping	B Aves
(c) Latin: birds	C Amphibia

Skill builder

10. Two animals (X and Y) live in a zoo. The zookeepers measured the air temperature and the body temperature of each animal at various times. The first measurements were taken just before sunrise. The last measurement was taken at 3 pm.
    (a) Present the data in the table in the form of a line graph, with air temperature on the horizontal axis and body temperature on the vertical axis. Use different colour lines for each animal.
    (b) **Identify** the animal that is an endotherm.
    (c) One of the animals is a reptile and the other is a bird. **Identify** the reptile.

	Body temperature (°C)	
Air temperature (°C)	Animal X	Animal Y
10	9	38
12	12	38
14	14	38
17	16	38
20	19	38
24	23	38
26	26	38
27	27	38

11. Use either the **Inspiration** or **Bubbl.us** weblink in the Resources tab to design a dichotomous key to separate and classify vertebrates into the five groups described in the figure on page 145. (You will need to download a trial version of the Inspiration software.)

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Complete this digital doc: Worksheet 4.7: Classifying vertebrates (doc-12375)

Explore more with this weblink: Inspiration or Bubbl.us

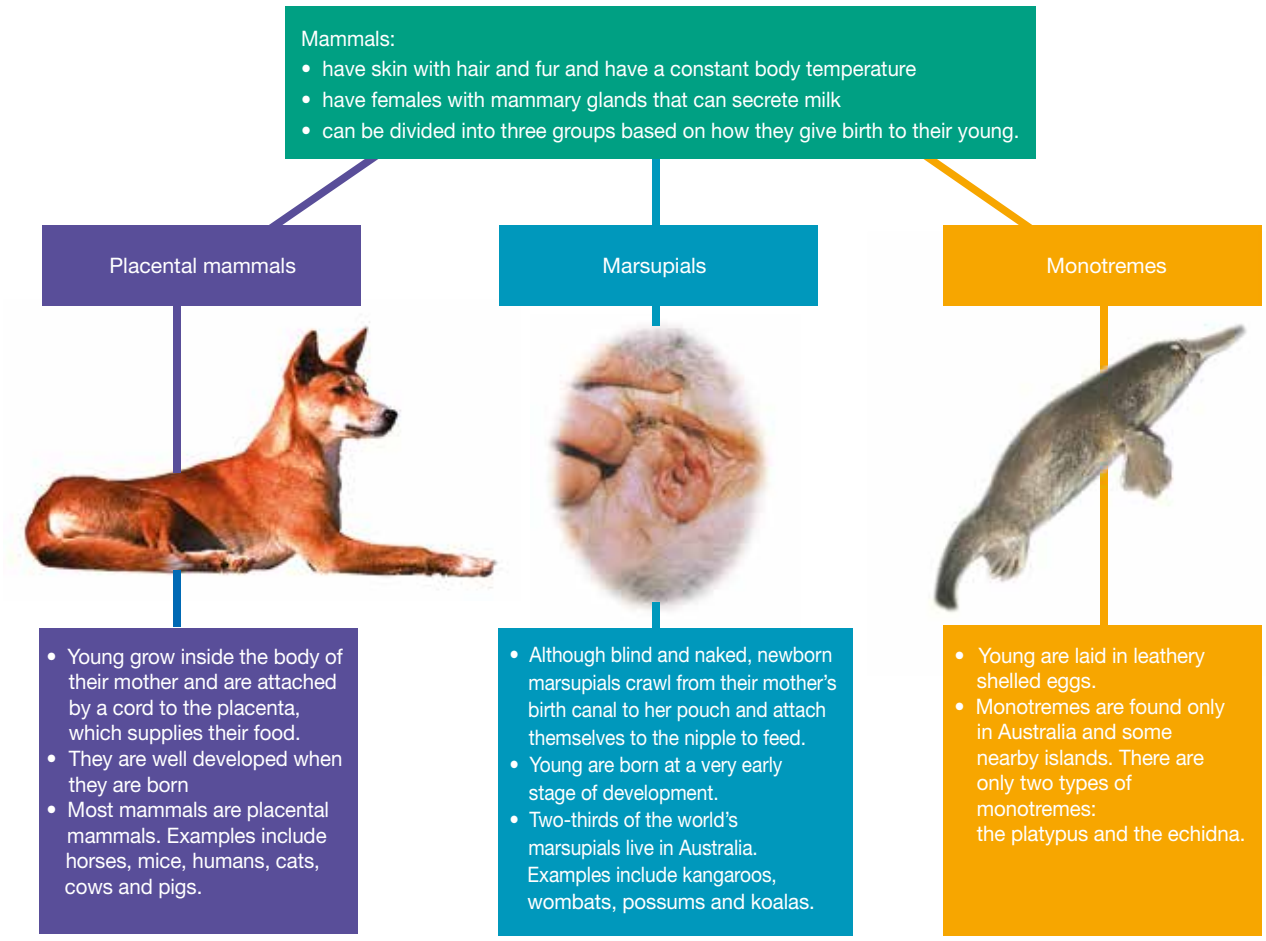
4.8 Surviving in the Australian environment

4.8.1 Australian mammals

Australia is home to unique species of animals and plants, including the only two egg-laying mammals. It is the driest continent on Earth and bushfires are a common occurrence. Australian soils are old and depleted of important nutrients. The animals and plants of Australia have evolved adaptations that enable them to cope with these extreme conditions.

There are three different types of mammals: placentals, marsupials and monotremes. These groups differ in how they give birth to their young. Most Australian mammals are marsupials.

- In most parts of the world except Australia, the majority of mammals are placental. Their young grow and develop inside the body of the mother, receiving nutrition and oxygen via a structure called the placenta.
- Marsupial mammals are born in a very underdeveloped stage. At birth they are no larger than a cherry tomato and crawl to a pouch where they attach to a teat. They remain in the pouch for many weeks, feeding on milk and completing their development. When they are mature enough, they spend increasingly longer periods of time out of the pouch but still suckle milk from a teat in the pouch.
- Monotremes lay eggs. The echidna and platypus are monotremes.



4.8.2 Adaptations

An adaptation is a feature that helps an organism to survive and reproduce in its environment. There are three main types of adaptations.

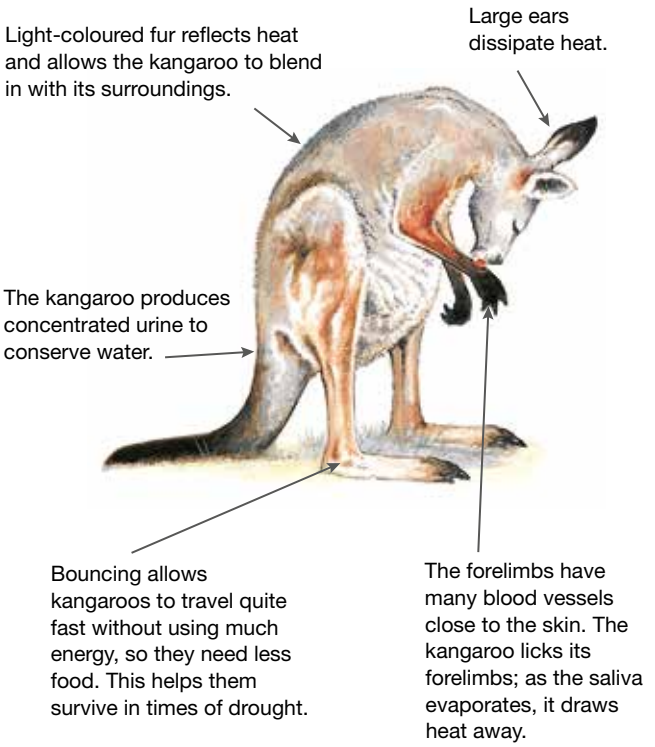
- Structural adaptations relate to the way the organism is 'built'. Size, fur colour, leaf shape, type of bark and flower colour are all structural adaptations.
- Physiological adaptations relate to how the organism works. Mammals produce milk to feed their young. Birds maintain a constant body temperature. Funnel web spiders kill their prey by injecting them with a powerful poison. These are physiological adaptations.
- A behaviour that increases an animal's chance of survival is a behavioural adaptation. Elephants cooling themselves by immersing their bodies in water and wombats spending most of the day in a burrow are examples of behavioural adaptations.

4.8.3 Kangaroos coping with hot dry conditions

Australia regularly experiences periods of extended drought, and in most regions of Australia summers are very hot. The eastern grey kangaroo has a number of adaptations that enable it to survive these conditions, including those shown in the diagram opposite.

The eastern grey kangaroo also has adaptations that maximise its chance of reproducing successfully despite the unpredictability of the environment. When conditions are good and grass is plentiful, a female kangaroo can have up to three offspring in various stages of development simultaneously. Very young joeys do not leave the pouch. As they get older the composition of the milk they suckle changes to match their needs. Once they are old enough to feed on grass, they begin to spend some time outside the pouch but continue to supplement their diet with milk from their mother. The mother is able to produce two different types of milk from different teats and have a young joey in the pouch while still feeding an older joey. More amazingly, she could also be carrying a third offspring in a suspended state of development. If one of her eggs has become fertilised and has started to develop into an embryo, its development is delayed until the youngest joey in the pouch has started

Adaptations that help a kangaroo survive in a dry environment



HOW ABOUT THAT!

Australia was once inhabited by megafauna: giant mammals including wombats the size of cars and lion-like marsupials called *Thylacoleo carnifex*. There were also giant flightless birds called *Genyornis* and a seven-metre long lizard by the name of *Megalania*.

The extinct giant kangaroo *Procoptodon* was heavily built and stood about 2.5 metres high. Procoptodons may have weighed about four times as much as the largest kangaroos of today. They had a short face and deep skull with huge molar teeth. Their molars may have helped them to eat tough plant foods. Procoptodons may have used their very long forelimbs to pull down the branches of trees and shrubs.

All members of the diprotodon group are extinct. They were the largest of all the marsupials. *Diprotodon optatum*, often referred to as the diprotodon, was the largest known marsupial to have ever lived. The skeleton of the diprotodon suggests that the animal was about the size of a rhinoceros, being about 3 metres long and possibly weighing about 2 tonnes.

to feed on grass, so that the pouch is now available. This is known as diapause. In periods of drought, male kangaroos usually do not produce sperm, so eggs are not fertilised, but joeys are produced in rapid succession when food is plentiful.

4.8.4 The platypus — a unique Australian

Imagine the disbelief of Europeans when the platypus was first described to them. This strange animal had webbed feet and a bill like a duck, but it had no feathers. It laid leathery eggs like lizards and crocodiles, but it did not have scales on its skin. It also had fur and a large tail like that of an otter but, like a reptile, it had only one opening for ejecting faeces and urine.

In London in 1799, an Australian sailor presented a platypus specimen to Dr George Shaw, a prominent biologist of the time. It was so strange that Shaw considered it a hoax and tried to cut off the duck-bill with scissors. The scissor marks are still visible on the preserved platypus skin in the British Museum (Natural History) in London.

We have since discovered a great deal about the platypus and its adaptations. It spends a large part of the day foraging for food in streams. The webbed feet are an adaptation that allow efficient movement in water. Fossils show that ancient platypus species had teeth, but the toothless bill of the modern-day platypus is well suited to its diet. The bill contains electroreceptors. These detect small electrical fields produced by the creatures the platypus feeds on. Platypus feed mainly at night; they do not rely on vision to locate their prey but, instead, sweep their bill rapidly from side to side along the murky banks of streams to find food. The male platypus has a highly venomous spur on each of its hind legs that it uses for defence.

4.8.5 Plant survival

Plants also have adaptations to cope with dry conditions. The diagrams at right show some of the adaptations of eucalyptus trees.

The platypus is one of the only two monotremes.



Adaptations that help eucalyptus trees survive in a dry environment



Woody fruits (gumnuts) protect seeds from drying out.



Leaves have a thick waxy cuticle to reduce water loss.



Blue-grey leaves reflect heat.

Leaves hang vertically so that a smaller area of the leaf is exposed to the sun in the middle of the day.

Bark has a light colour to reflect heat.

HOW ABOUT THAT!

Have you ever noticed that many Australian flowers do not have the large, brightly coloured petals seen in other flowering plants? The colour and scent of petals attracts pollinators (the birds, insects and other animals that transfer pollen from one flower to another). In many Australian native species, the same function is carried out by parts of the flower that also have another function; often, the stamens and pistils are the brightly coloured parts of Australian natives. By not producing large petals, these plants are able to conserve water and energy.

Another adaptation seen in many Australian flowers, including *Banksia* and bottlebrush species, is that flowers are clustered together into a structure that looks like a single flower but is actually made up of many small flowers. When they are organised in this way, the flowers are more visible, particularly from a distance, and thus more likely to be visited by pollinators.

This looks like a single *Banksia* flower, but it is actually made up of many small flowers clustered together.



4.8 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. **Construct** a three-column table and use it to summarise the main characteristics of each of the three groups of mammals.
2. **Outline** how marsupials differ from all other mammals.
3. How did placental mammals get their name?
4. **Identify** which group of mammals the echidna belongs to. What other animal belongs to this group?

Think

5. **Classify** each of the adaptations below as structural, behavioural or physiological.
   (a) Producing small amounts of very concentrated urine
   (b) Large ears to dissipate heat
   (c) Licking forelimbs when hot
   (d) Foraging for food by sweeping its bill from side to side
   (e) Thick waxy cuticle on leaves
   (f) Brightly coloured stamens
6. **Identify** which features of the platypus and other monotremes are:
   (a) like those of placental mammals
   (b) unlike those of placental mammals.

Investigate

7. The banksia is a group of Australian plant species with adaptations for drought tolerance and coping with frequent bushfires. **Investigate** some of these adaptations and **summarise** the information by labelling a photo in a similar way to the diagram of the eastern grey kangaroo.

8. Research the adaptations of an Australian animal not covered in this section. **Summarise** the adaptations in a table with the following headings: 'Structural adaptations', 'Physiological adaptations, 'Behavioural adaptations'.
9. Did you know that adult hedgehogs have 5000 spines? So that the birth canal is not damaged when the mother is giving birth, the initial spines of a newborn are covered with a layer of skin. The spines pop through the skin hours after birth. Although hedgehogs are mammals and they look a little like echidnas because of their spines, they are not classified as monotremes.
   (a) Find out whether hedgehogs are placental mammals or marsupials.
   (b) **Outline** how hedgehogs differ from echidnas.
   (c) A porcupine also has spines. **Identify** the group of mammals that a porcupine belongs to.
   (d) How are porcupines different from hedgehogs and echidnas?
10. Use the **Naracoorte Fossil Mammal Site** weblink in the Resources tab. Watch the movie and **outline** why there are so many fossils at Naracoorte.
11. Use the internet to find more examples of Australian megafauna and prepare two PowerPoint slides about one of these examples. On one slide, include a picture of what the animal may have looked like. On the other slide, include any interesting facts you find, such as the size of the animal and its diet.

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Explore more with this weblink: Naracoorte Fossil Mammal Site

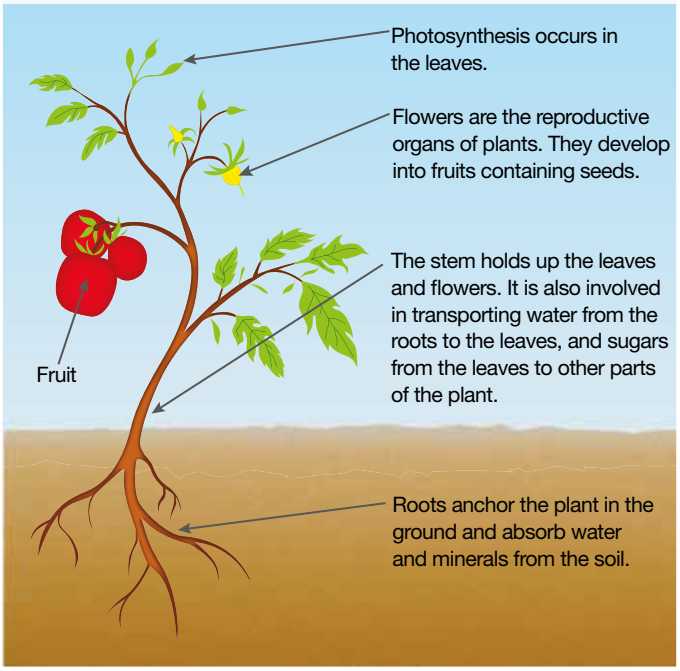
4.9 Classifying plants

4.9.1 Roots, stems and leaves

To classify plants, biologists rely on structural features as well as the plant's mode of reproduction. Some plants produce flowers, others produce seeds but no flowers, and some produce spores rather than seeds. The key on page 152 can be used to sort plants into their main divisions. The characteristics used in the key are explained below.

If you were asked to draw a plant you would probably draw a tree or a plant similar to the diagram below. We tend to think of plants as having roots, leaves, and one or more stems. In fact only some groups of plants have these structures. Seaweed has a structure called a holdfast that anchors it to the sea or river bed, but a holdfast is not a true root because it cannot absorb water or nutrients from the ground. Seaweed has flat structures called blades that appear similar to leaves, but these do not have veins and are not true leaves. Mosses have simple structures that look a bit like roots, stems and leaves but, as these do not contain the same structures for conducting water and other substances throughout the plant, they are not considered to be true roots, stems and leaves. The leaf-like structures of mosses are very simple and usually only one cell thick.

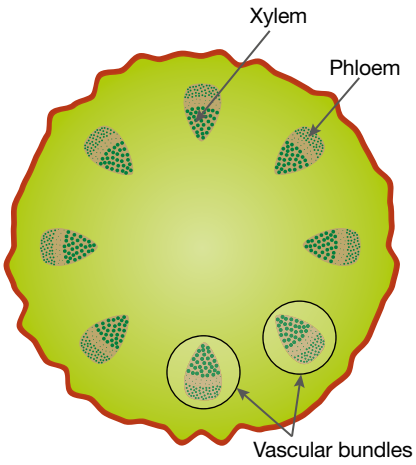
Some plants have leaves, roots and one or more stems.



4.9.2 Conducting tissue

When a piece of celery is left in red dye overnight, some of the red dye can be seen in the veins of the celery leaves. Celery, like many other plants, contains conducting tissue. There are two types of conducting tissue in plants: xylem and phloem. **Xylem** carries water and minerals from the roots up to the leaves. **Phloem** carries mainly sugars, often from the leaves to other parts of the plant, but also in other directions as well. Algae and mosses lack conducting tissue.

If we cut through the stem of a plant, we can see the conducting tissue, organised in vascular bundles. In many plants, the vascular bundles are organised in a ring.

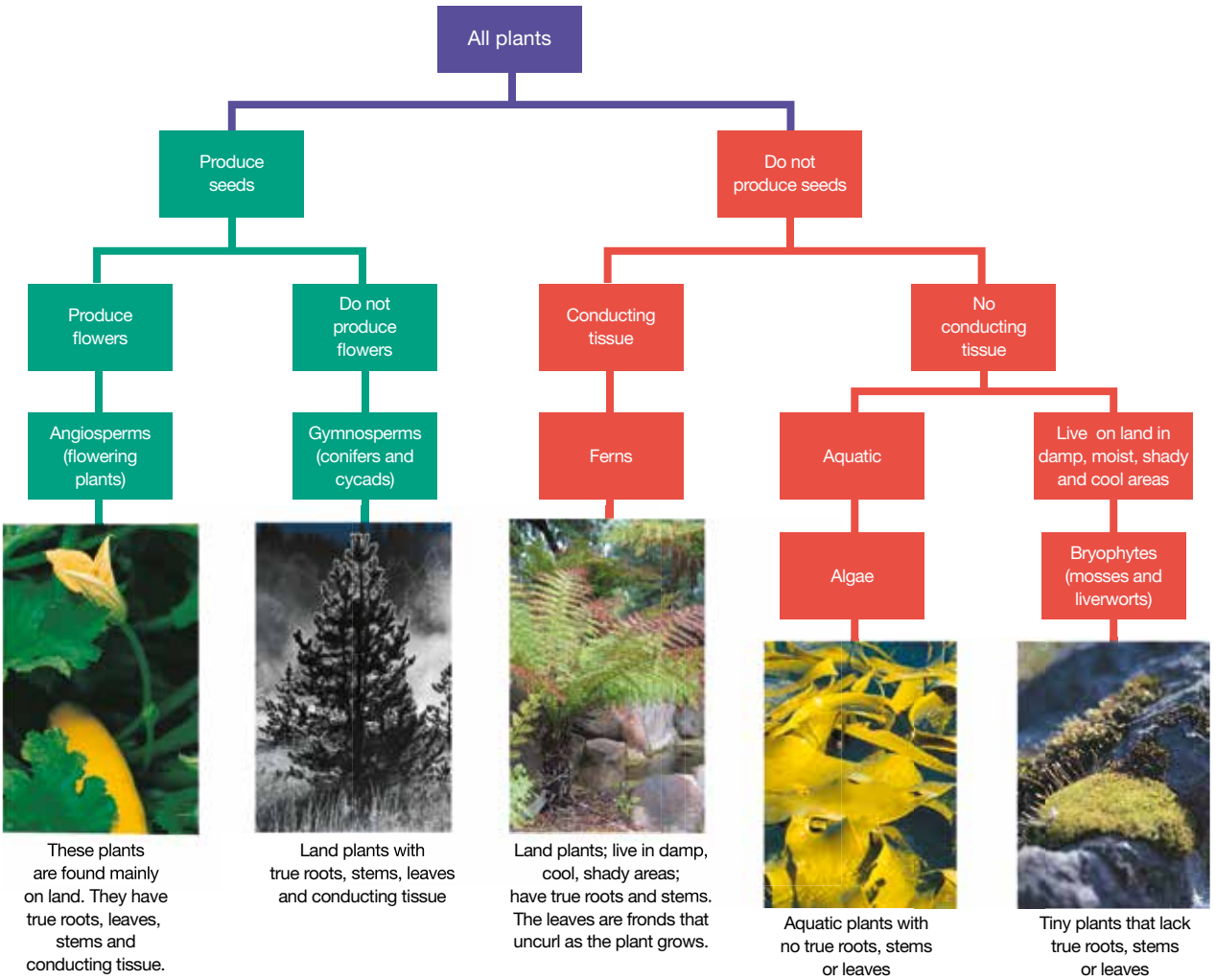


4.9.3 Reproductive structures

The group of plants we tend to be most familiar with are flowering plants. Some flowers such as roses, lilies and agapanthus, are very obvious. Grasses on the other hand produce tiny inconspicuous flowers. Flowers contain the reproductive organs of the plant. Once a flower has been pollinated, it develops into a fruit that contains seeds from which new plants may eventually germinate.

Conifers are a group of plants that produce seeds but not flowers. Cones develop on both male and female conifers. The male cones are

Plants can be classified into five main groups.



small and produce pollen. The female cones are larger. They contain the ovules, which develop into seeds after fertilisation.

Simple plants produce spores instead of seeds. One important difference between seeds and spores is that seeds contain stored food. When the seed germinates (sprouts), the developing plant can use the food stored in the seed until it has developed leaves and can photosynthesise. Another important difference is that spores are not the result of fertilisation.

INVESTIGATION 4.5

Investigating plant groups

AIM: To investigate features of some plant groups

You will need:
two pine cones
fern frond (with sporangia)
some moss
piece of seaweed
weed pulled out of the ground (with roots attached)
camera (such as digital camera, webcam or mobile phone camera)

- Create a table with the following column headings: 'Group', 'Photo'.
- Take a photo of each plant or plant part. Insert the photos in the table you created and write down the group name for each photo.
- Add labels to the photos. Label the following.
  - Scales on the pine cone
  - Sorus on the underside of the fern frond (The sori are the brown dots. Each sorus is a cluster of sporangia. The sporangia contain spores.)
  - Blade of the seaweed
  - One single moss plant
  - Roots, stem and a leaf of the weed
- Leave one pine cone in a warm dry area overnight and place the other pine cone in water for one hour (or overnight).
- Place the fern frond on a white piece of paper (with the sori on the bottom). Leave for an hour (or overnight).

Discussion

1. Look closely at the pine cone that was left in the dry environment. Can you see any seeds between the scales? Can you get any of the seeds to fall out?
2. Suggest how pine seeds are dispersed (spread out) from the tree.
3. Observe the pine cone that was left in water. In what way is it different from the dry cone? What causes pine cones to open and close?
4. Where are some good places to find moss? Suggest why.
5. Mosses are tiny plants. Suggest why they cannot grow much taller than a few centimetres.
6. Observe the white paper on which the fern was left. What has fallen on it?

DISCUSSION

Take a walk around the school grounds and use the key opposite to classify some of the plants you encounter. Which group is most common?

4.9 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. **Define** the following terms relating to plants: ‘holdfast’, ‘blade’, ‘spore’, ‘vascular tissue’.
2. **Identify** the substance(s) transported by xylem and phloem tissue.
3. **Outline** one difference between seeds and spores.
4. **Distinguish** between mosses and ferns.
5. **Identify** which groups of plants have conducting tissue.
6. **Distinguish** between conifers and flowering plants.

Think

7. Write the following steps of the life of a flower in the correct sequence, starting with flower formation: flower formation, seed dispersal, pollination, germination, fertilisation, plant grows.
8. Moss and mould are often confused. Mould is actually a fungus rather than a plant.
   (a) Suggest why moss and mould are confused.
   (b) Imagine that your 8-year-old cousin was pointing at some moss and said: ‘Look. There is mould growing over there!’ How could you explain the difference between moss and mould in a way that an 8 year old would understand?
9. A description of three plant specimens follows. **Identify** the plant group that each may belong to.
   (a) A plant with needle-like leaves and seeds that form inside cones
   (b) A plant with an obvious root system, a stem, leaves and with fruit containing seeds
   (c) A plant found in a cool, shady rainforest, with a horizontal stem and curled up new leaves with rows of brown spots underneath them
10. **Identify** which plant group the plant below belongs to.



11. (a) Which of the two plants below is more closely related to *Callistemon pachyphyllus*? **Explain** how you can tell from the names of the plants. (*Hint:* See Section 4.2 on page 124 Why classify?).

Grevillea banksii



Callistemon citrinus



(b) **Explain** why the name *Callistemon pachyphyllus* is written in italics but not the name bottlebrush.

Investigate

12. Many flowering plants are useful to humans as food and for manufacturing products such as paper and furniture. Many of the chemicals used to make medicines, dyes and cosmetics are extracted from flowering plants. Find pictures of plants that are useful to humans and create a collage entitled 'Flowering plants – an important resource'.
13. Use the **Classifying life** weblink in the Resources tab to work through the classification of an orchid from kingdom to species.

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Explore more with this weblink: Classifying life

learnon

4.10 Project: Snakes alive!

Scenario



Every year in Australia, an average of around 4000 people are bitten by snakes. Some of these snakes are non-venomous and their bite results in little more than a nasty wound, but many are venomous with a bite that is deadly unless medical intervention can be reached in time — in fact, Australia has more venomous snake species than any other country in the world! You can encounter a snake just about anywhere — on bushwalking trails, in your back garden, in a shed, even swimming in the ocean — so it is really important that you know what kind of snake you are looking at.

Your task



Your group has been approached by State Parks and Wildlife to create a Snake Safety brochure, copies of which will be sent out to all bushwalking clubs and National Park centres in your state for distribution to bushwalkers, campers and nature lovers. The main part of the brochure will be an easy-to-follow identification key that allows the reader to quickly and easily determine the species of snake they have encountered and so learn whether it is venomous or non-venomous. The brochure will also contain a diagram indicating on a state map where different venomous species are usually found, as well as advice on what to do if you encounter a snake and what first aid you should render if someone is bitten by a venomous or non-venomous snake. You may also like to include some interesting snake statistics, or a Snake Fact or Fiction section.

SUGGESTED SOFTWARE

- ProjectsPLUS
- Microsoft Publisher
- Word processing software
- Internet access

4.11 Review

4.11.1 Study checklist

Why classify?

- **explain** why biologists classify living things 4.2
- **describe** the hierarchy of classification 4.2
- **outline** why each species is given a unique scientific name made up of two words 4.2

Characteristics of living things

- **describe** the characteristics of living things 4.3
- **define** the terms 'respiration', 'assimilation', 'response', 'growth' and 'reproduction' 4.3
- **distinguish** between dead and non-living things 4.3

Identification keys

- interpret and **construct** dichotomous keys including branching keys, tabular keys and circular keys 4.4, 4.6, 4.7, 4.9

Animal groups

- **distinguish** between vertebrates and invertebrates 4.7
- **describe** the features of vertebrates 4.7
- **classify** vertebrates as birds, mammals, reptiles, amphibians or fish based on their characteristics 4.7
- **distinguish** between placental, monotreme and marsupial mammals 4.8
- **classify** invertebrates into their phyla using a dichotomous key 4.6

Plant groups

- **describe** the features used to classify plants into major groups 4.9
- use a dichotomous key to **classify** a plant into one of the five major plant groups 4.9

Adaptations

- **define** the term 'adaptation' 4.8
- **describe** adaptations of Australian animals and plants to their environment 4.8

Individual pathways

ACTIVITY 4.1
Classification
doc-10541

ACTIVITY 4.2
Investigating classification
doc-10542

ACTIVITY 4.3
Developing classification
doc-10543

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FOCUS ACTIVITY

online only

Create a poster that explains the different levels of classification (kingdom, phylum, class, order, family, genus, species) using human classification as an example.
Access more details about focus activities in the Resources tab (doc-10540).

4.11 Review 1: Looking back

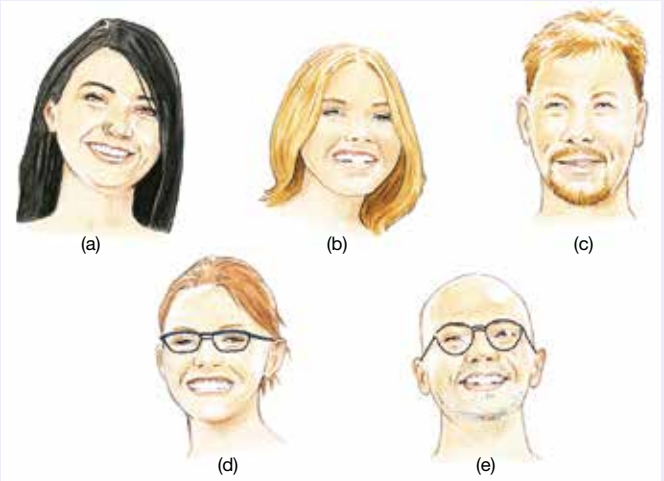
assessON

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 each term in the table below with its definition.

Term	Definition
(a) Exoskeleton	A Flat worms
(b) Vertebrate	B Flowering plants
(c) Monotreme	C Invertebrate with paired, jointed legs and an exoskeleton
(d) Echinoderm	D Plant that produces seeds but not flowers
(e) Angiosperm	E Warm-blooded vertebrate that feeds its young with milk
(f) Dichotomous key	F Internal skeleton
(g) Mammal	G Invertebrate with rough, spiny skin and tube feet; body has five sections
(h) Reptile	H Unicellular organism with a true nucleus
(i) Platyhelminthes	I Feature that helps an organism survive in its environment
(j) Gymnosperm	J Egg-laying mammal
(k) Adaptation	K Multicellular organism that photosynthesises; cells have a cell wall and chloroplasts
(l) Endoskeleton	L Animal that has a backbone
(m) Arthropod	M A key where each level has only two options
(n) Plant	N External skeleton
(o) Protist	O Scaly vertebrate that lays eggs with a leathery shell

2. **Outline** the seven characteristics of living things.
3. **Explain** why the Asimo robot is not a living organism.
4. **Explain** why it is useful to classify organisms.
5. **Identify** the seven levels of classification in order from the highest level to the lowest level.
6. Use the following key to **classify** the people shown below.
   1. Glasses .....Go to 2
   1. No glasses .....Go to 3
   2. Female .....Anna
   3. Male ..... Tom
   4. Nose ring ..... Emily
   5. No nose ring ..... Go to 4
   6. Beard .....Jason
   7. No beard .....Jossie



7. When scientists discover a new organism, they give it a unique scientific name. **Describe** how that name is created.
8. **Outline** one way that the invention of the microscope had an impact on classification.
9. **Distinguish** between each of the following pairs.
   (a) Animals and plants
   (b) Plants and fungi
   (c) Fungi and bacteria

10. **Distinguish** between endoskeletons and exoskeletons.
11. **Outline** the features of vertebrates.
12. **Distinguish** between monotreme mammals, marsupial mammals and placental mammals.
13. **Classify** the following invertebrates using the key in section 4.6 on page 141.



14. **Construct** a dichotomous key to classify the aliens shown below.



Test yourself

1. Which of the following is *not* a reason for classifying living things?
   (A) It makes communication between scientists easier.
   (B) It is the first step towards conserving biodiversity.
   (C) It provides information about evolutionary relationships.
   (D) It ensures that changes are not made to existing classification schemes. **(1 mark)**
2. Which of the following is a structural feature?
   (A) Webbed feet
   (B) Building a nest prior to laying eggs
   (C) Detecting prey by sweeping bill sideways
   (D) Producing highly toxic venom **(1 mark)**
3. **Identify** which kingdom moss belongs to.
   (A) Animalia
   (B) Plantae
   (C) Fungi
   (D) Protista **(1 mark)**
4. Which statement is correct?
   (A) Protozoa and bacteria are groups of micro-organisms.
   (B) Fungi cells have chloroplasts.
   (C) Plant cells lack a true nucleus.
   (D) Staphylococci are spiral shaped. **(1 mark)**
5. **Compare** each of the following pairs.
   (a) Birds and reptiles
   (b) Vertebrates and invertebrates
   (c) Monotremes and placental mammals
   (d) Amphibians and fish
   (e) Bacteria and fungi
   (f) Conifers and flowering plants **(3 marks)**
6. Select an Australian animal and **describe** three adaptations that it has. **Explain** how each adaptation helps the animal survive in its environment. **(2 marks)**

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Complete this digital doc: Worksheet 4.8: Classification puzzles (doc-12376)

Complete this digital doc: Worksheet 4.9: Classification summary (doc-12377)

TOPIC 5
Separating mixtures

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?

Chocolate is a mixture of ingredients — cocoa, butter, sugar, milk and flavours — blended to give a great taste. The sugary coating is a mixture too. Even the colouring can be a combination of many different colours.

Chocolate isn't the only substance that can be made by combining different ingredients. Many substances are made this way. And, the individual ingredients in some substances can also be separated further into parts.

LEARNING SEQUENCE

5.1	Overview	160
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5.3	Looking for solutions	166
5.4	Mixing insoluble substances	170
5.5	Separate ways	172
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Each of these sweets contains a mixture of ingredients including cocoa, butter, sugar, milk, flavours and colours.



Separating mixtures

Imagine that a few small iron nails have been dropped into a child's sandpit and have sunk into the sand so that they can't be seen. One way of separating the nails from the sand is to use a magnet. This works because the nails and sand have different **properties**, or features. The nails are made from a substance that is attracted to magnets, but the sand is not attracted to magnets.

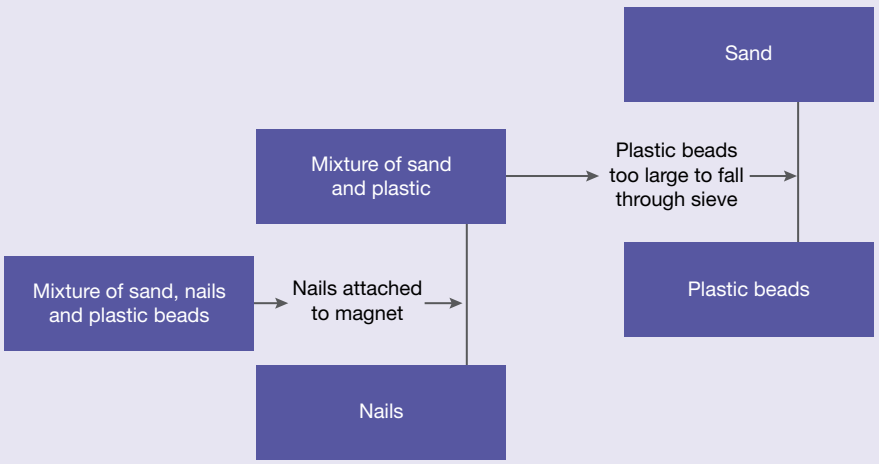
But what if plastic beads had been dropped into the sandpit instead of nails? They can't be separated from the sand with a magnet. The key to separating them is recognising the different properties of the plastic beads and the sand. An obvious difference is size. The plastic beads are much bigger than grains of sand. A child's sand sieve would do the trick. Sand grains pass through but the plastic beads don't.

The flow chart below shows one way of separating the parts of a mixture of sand, nails and plastic beads.

1. Suggest another method of separating the nails from the sand.
2. What difference in properties does your suggested method use to separate the substances?
3. Draw a flow chart to show a different method of separating the sand, nails and plastic beads from the one shown in the flow chart below.

Chocolate is a mixture of cocoa, butter, sugar, milk and flavours.





INVESTIGATION 5.1

Design and separate

AIM: To investigate properties used to separate mixtures

Your task is to separate the parts of a mixture of matches, pebbles, steel paperclips and sand.

You will need:

sand (about 250 mL)
small pebbles
plastic container (about 500 mL)
other equipment and water as required
'dead' matches
steel paperclips
A3 paper

- Mix the matches, pebbles and paperclips evenly in a plastic container of sand.
- Devise and write a step-by-step plan of a method to separate the four parts. You will need to think about the properties of each part of the mixture that will make separation possible.
- Make a list of all of the equipment that you will need.
- Check your plan with your teacher, and then gather the equipment and perform the separation.
- On A3 paper, draw a flow chart like the one above to show how each part was separated from the mixture.

5.2 Pure substances and mixtures

5.2.1 Pure substances and mixtures

Is this a mixture or a pure substance?



Consider the water in this glass. It looks like it has come straight from a tap, but what can we tell about the composition of the liquid in this glass just by looking at it? Can we say for sure that it is pure water? And what exactly do we mean by pure anyway?

You will recall from topic 3 that all matter is made up of particles and that there are many different types of particle. Substances in our world can generally be classified as being either **pure substances** or **mixtures** according to the kinds of particles they contain and how these are arranged.

A pure substance is made up of the same type of particle throughout. White table sugar that you put on your breakfast cereal, for example, is a pure substance and is made up of nothing except identical particles of sucrose. Oxygen gas, fine gold and distilled water (which has been processed so that it is free of pollutants and minerals) are also examples of pure substances. The particles in a pure substance all have the same physical and chemical properties.

A mixture, on the other hand, is made up of at least two substances that have different properties and so it contains several different kinds of particle. Sea water is an example of a mixture because it is made up of water particles and salt particles. Tap water in most cities is also a mixture of water and other substances, such as chlorine, sodium, calcium, magnesium and fluoride.

Chocolate milk is an example of a mixture because it is made up of particles of milk (which is itself a mixture), sugar and cocoa. Some other common mixtures are shown in the table below.

In most cases, it can be difficult to tell whether a substance is a pure substance or a mixture just by looking at it. This is because the individual particles in the substance are usually too small to see, so it is hard to tell if they all look the same or if there are different types of particle present.

Mixture	Made up of …
Salt water	Water, salt
White coffee	Water, coffee, milk (may have sugar)
Chocolate	Cocoa, milk, sugar, cocoa butter
Cola drink	Water, carbon dioxide, sugar, caramel, colouring agents, flavouring agents
Soil	Silica, iron oxide, organic matter, nitrogen
Bread	Flour, yeast, water, egg, sugar

5.2.2 Recycling plants

Most local councils have a **recycling program**. Items such as paper, all plastic bottles and containers, glass, aluminium and steel can be recycled and made into new products. Recycling reduces the amount of waste that goes to **landfill** and saves precious resources such as trees and bushland. Many **manufacturing processes** pollute the environment. Recycling and reusing materials reduces the need to manufacture from raw materials.

5.2.3 Separating by sight



Household rubbish is usually a mixture of food scraps, recyclable materials and other waste. The first step in recycling is to **separate** the recyclable items from other household rubbish. We can see the differences between the types of rubbish, and we know which items can be recycled. Big recycling plants use this knowledge to separate the tonnes of recycled goods they receive.

5.2.4 Separating mixtures

Many mixtures can be separated into the basic substances that they are made of. There are a number of different ways of doing this, but all of these methods rely on the fact that the individual substances that make up a mixture have different properties.

For example, after you've cooked pasta, you separate the cooked pasta (solid and in hollow cylinders) from the water (liquid) using a strainer. Water passes easily through the strainer, but the pasta is caught.

If you are doing woodwork and you drop some nails in the sawdust, there are several ways to separate them because their properties are so different.

5.2 Exercises: Understanding and inquiring

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 'mixture'.
2. **Explain** why some mixtures are easier to separate than others.
3. How can you **distinguish** pure substances from mixtures?
4. **Recall** two reasons why recycling is good for the environment.
5. **Explain** why recyclable materials need to be separated.

Think

6. **Describe** all the properties you can think of for:
   (a) salt
   (b) sand
   (c) water.
7. **Explain** how you would separate the parts of a mixture of salt, sand and water. Use the properties that you considered in question 6.
8. Imagine you dropped nails in the sawdust in woodwork class. **Propose** two reliable ways of separating the nails from the sawdust.
9. **Construct** a table with two columns with the headings 'Pure substance' and 'Mixture'. List the following substances under the appropriate heading: freshly made apple juice, tap water, soft drink, cake batter, sterling silver, distilled water, gold nugget, glass, cornflakes.
   You may have to research some of these substances to find out which column they belong to.
10. **Construct** a table like the one below and complete it with information on separating recyclable rubbish.

Method	What is removed?	Properties

(a) Record the methods used to separate different types of material in a recycling plant.
(b) For each method, record which material is removed from the flow of rubbish.
(c) What properties of this material allow it to be separated from the mixture?

11. **Deduce** why the same magnets are not used for separating both aluminium and steel cans.
12. **Explain** why people, rather than machines, need to manually separate some of the recycling mixture.

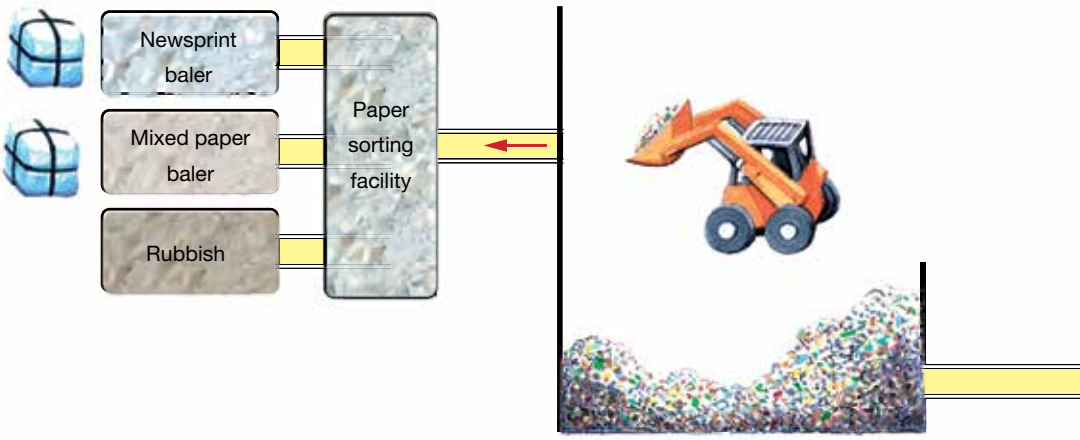
Investigate

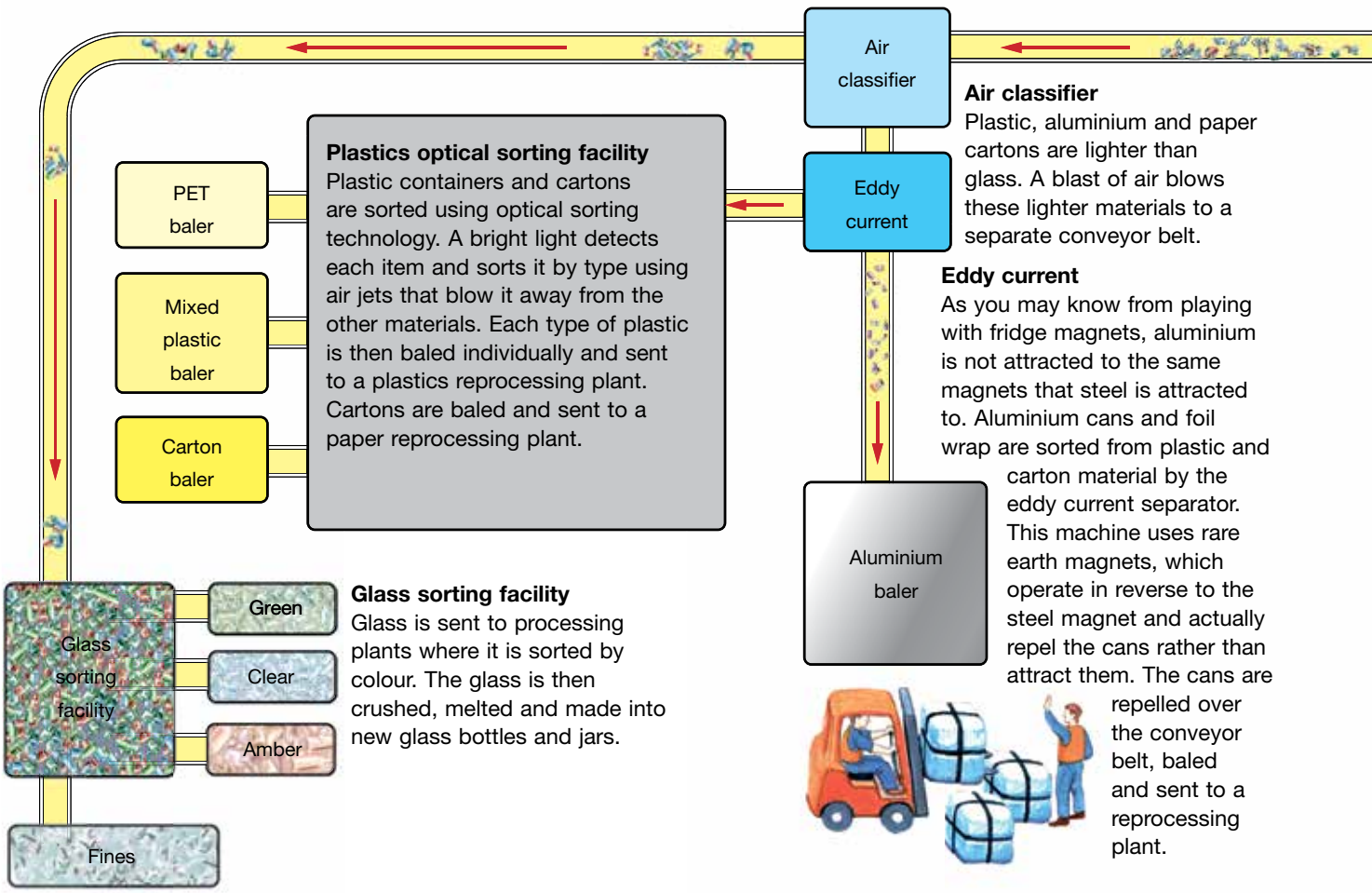
13. How would you separate the sand from a mixture of sand and sawdust? **Construct** a flow chart to show the steps you would use. Check your method with your teacher before trying out your experiment.

Create

14. Design and **construct** a poster or brochure that explains which items can be recycled. Check with your local council about how they prefer recycling materials to be separated ready for collection. Include this in your brochure or poster.

Paper sorting facility
All paper and cardboard is manually sorted to ensure that there are no plastic bags or other non-paper items in the mixture. Paper and cardboard are baled and sent to **paper mills** for reprocessing. At the mill, paper is shredded and mixed with water (pulped) to make new paper products such as cardboard boxes.





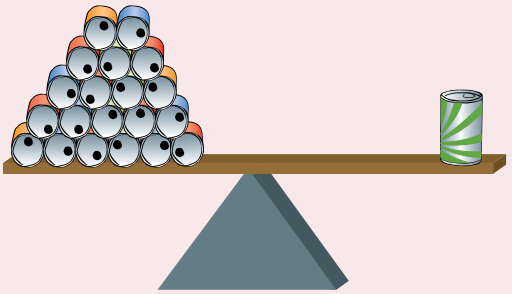
Air classifier
Plastic, aluminium and paper cartons are lighter than glass. A blast of air blows these lighter materials to a separate conveyor belt.

Eddy current
As you may know from playing with fridge magnets, aluminium is not attracted to the same magnets that steel is attracted to. Aluminium cans and foil wrap are sorted from plastic and carton material by the eddy current separator. This machine uses rare earth magnets, which operate in reverse to the steel magnet and actually repel the cans rather than attract them. The cans are repelled over the conveyor belt, baled and sent to a reprocessing plant.

Glass sorting facility
Glass is sent to processing plants where it is sorted by colour. The glass is then crushed, melted and made into new glass bottles and jars.

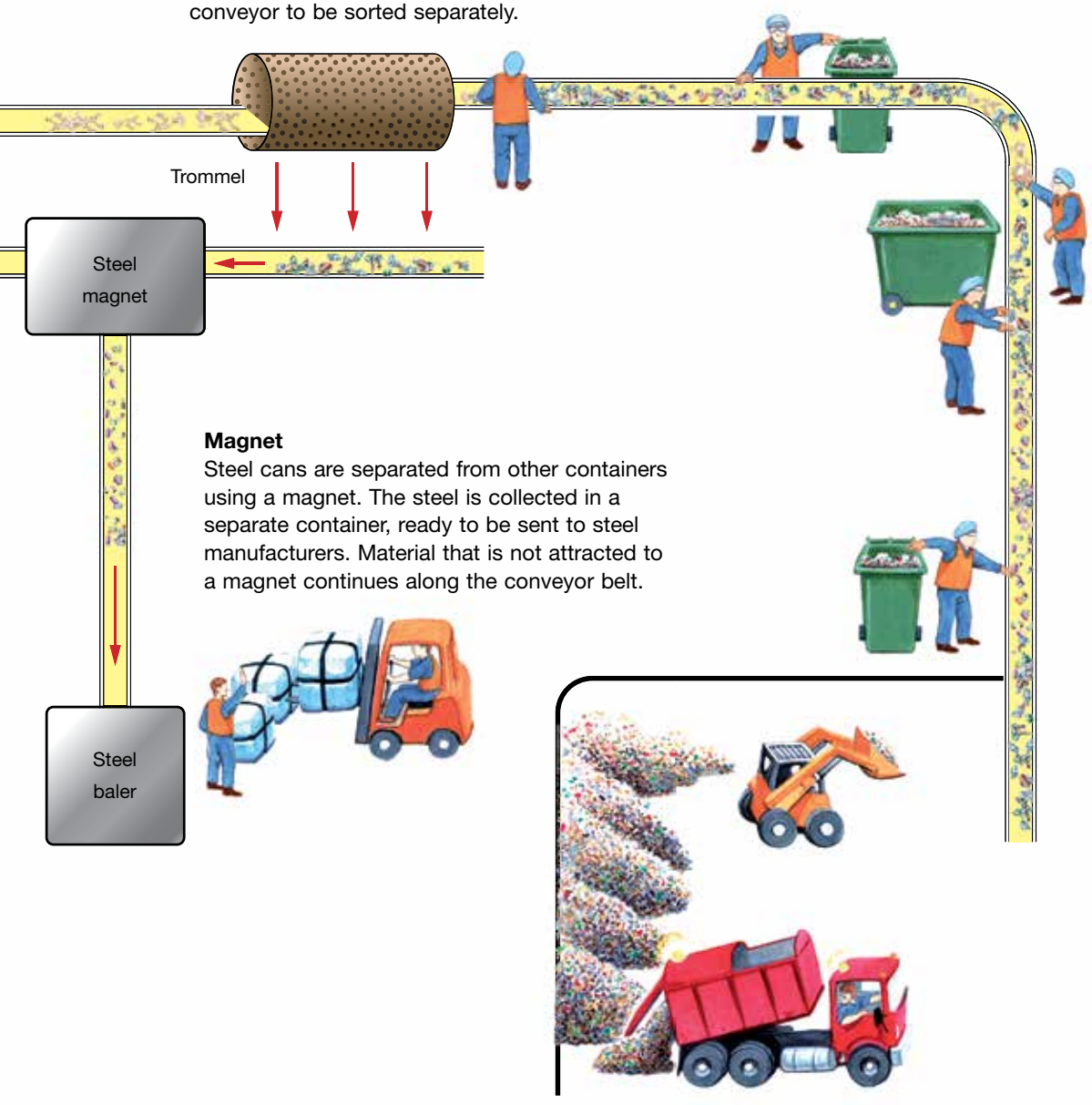
HOW ABOUT THAT!

It takes the same amount of energy to make 20 cans from recycled aluminium as it does to make just one new can from raw materials.



Trommel
The trommel is a large rotating cylinder with holes along its sides, similar to the inside of a washing machine. Heavy recyclables, such as plastic, glass, cartons, steel and aluminium, fall through the holes in the trommel, while lightweight material, such as paper and cardboard, continue along the conveyor to be sorted separately.

Pre-sort
When the mixture of goods arrives at the sorting facility, it is sent along a conveyor belt. Staff sort through the materials by hand to remove any non-recyclable material that they can see in the mixture, such as plastic bags, foam, garden waste and household rubbish.



Magnet
Steel cans are separated from other containers using a magnet. The steel is collected in a separate container, ready to be sent to steel manufacturers. Material that is not attracted to a magnet continues along the conveyor belt.

learnon RESOURCES — ONLINE ONLY

Watch this eLesson: Lavoisier and hydrogen (eles-1772)

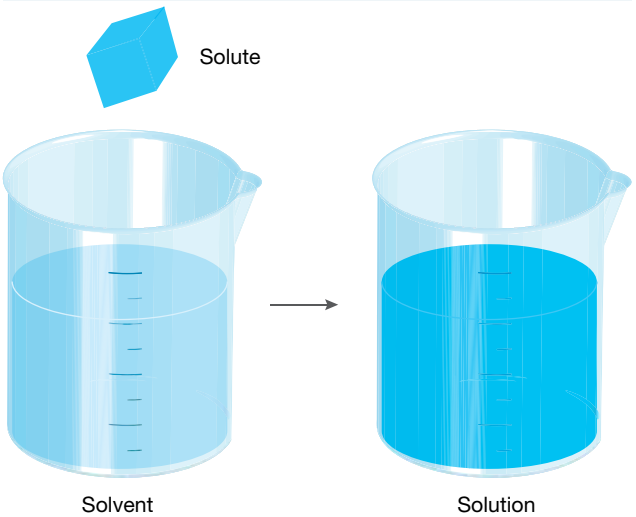
5.3 Looking for solutions

5.3.1 What is a solution?

When you add a teaspoon of sugar to a cup of hot water and stir it, the sugar crystals seem to disappear. Where have they gone? Actually, the sugar is still there; the sugar particles have been separated away from each other and have spread out among the water particles. As the individual particles of sugar are so small, they are unable to be seen with the naked eye. We say that the sugar has **dissolved** in the hot water and has formed a sugar solution.

A **solution** is a mixture made up of one substance dissolved in another. The substance that is dissolved is called the **solute**, and this can be a solid, a liquid or even a gas. The substance that the solute is dissolved in is called the **solvent**; this is usually a liquid. In the case of our sugar and hot water, the sugar is the solute and the water is the solvent. Water is considered to be a very good solvent because many chemicals dissolve in it quite easily. Solutions in which water is the solvent are said to be **aqueous solutions**.

A solute dissolves in a solvent and creates a solution.



When the carbon dioxide is dissolved, you can't see that it's there. When you open the container, the pressure is reduced. The carbon dioxide is separated from the mixture and bubbles to the surface.



5.3.2 Solutes

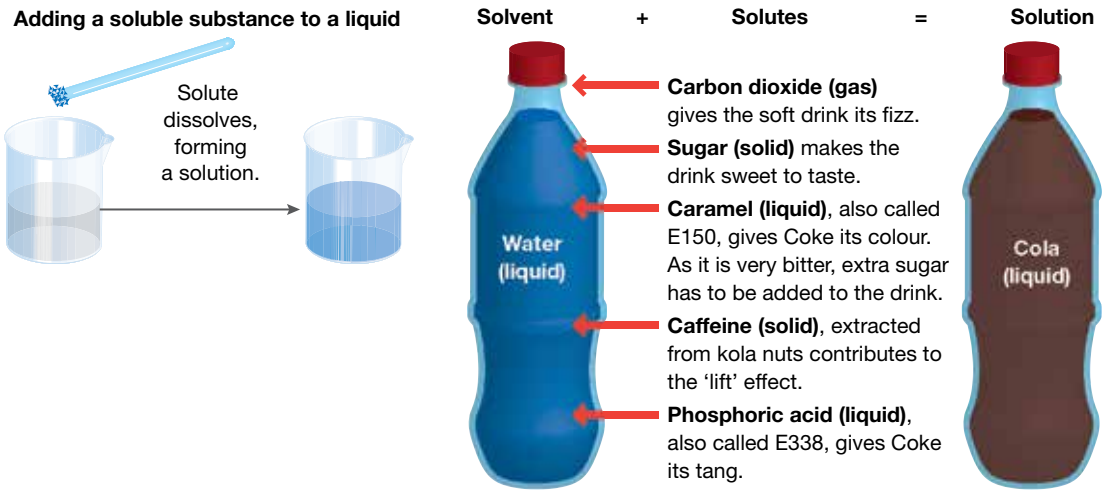
The solute in a solution can be any state of matter. When we dissolve things such as sugar or salt, the solute is a solid. When we add cordial to water, the cordial dissolves in the water; in this case, the solute is in a liquid form.

A solution does not have to have just one solute dissolved in it though — a substance such as a fizzy drink has many different substances dissolved in water, some of which are solid and some liquid, as well as the gas carbon dioxide that gives it the fizz.

The carbon dioxide is pumped into the bottles or cans at high pressure. The bottles and cans are then sealed to keep the carbon dioxide dissolved in the solution. When you open the drink, the pressure is reduced and the carbon dioxide bubbles out of solution.

5.3.3 Soluble or insoluble?

Substances that dissolve in a particular solvent are said to be **soluble** in that solvent. Remember that, just because a substance is soluble in one solvent, doesn't mean that it is soluble in all solvents. For example, waterproof ink (which you will find in permanent markers) is soluble in alcohol but it is *not* soluble in water. We use the word **insoluble** when a substance does not dissolve in a particular solvent.



5.3.4 Time to concentrate!

When you are making up a cordial solution, you dissolve cordial syrup in water. If you add only a little bit of syrup to the water, you get a very pale cordial drink, which tastes only slightly of the cordial. However, the more syrup that you add, the darker the colour of your cordial drink and the stronger the taste will be. The relative amount of solute (in this case, the cordial syrup) compared with the amount of solvent (water) determines the **concentration** of the resulting solution.

The amount of solute dissolved in the solvent determines the concentration of the solution.



The concentration of a solution is a measure of how much solute has been dissolved in a fixed amount of solvent. Solutions in which there is very little dissolved solute are said to be **dilute** solutions while those that have a great deal of solute dissolved in them are called **concentrated** solutions.

There is a limit to how concentrated you can make a solution. Eventually, as you add increasing amounts of solute to a solvent, you reach a point at which no more solute dissolves — this is referred to as **saturation**. Solute added to a saturated solution simply remains undissolved in the container.

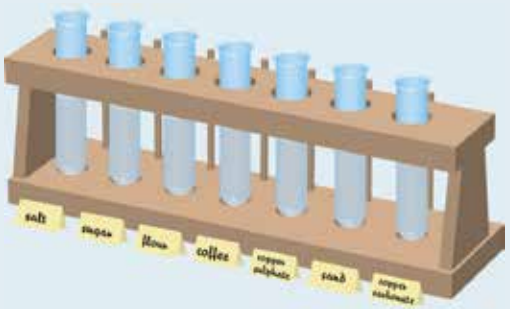
The concentration of a solution is usually described in terms of the mass of solute dissolved in a fixed amount (usually 1 litre) of solvent. For example, a salt solution that is made up of 5 grams of salt and 100 mL of water would have the same concentration as a solution with 50 grams of salt in 1000 mL of water. Both solutions would have a concentration of 50 g/L.

INVESTIGATION 5.2

Soluble or insoluble?

AIM: To investigate the solubility of some common substances in water

Substances that dissolve are said to be soluble. Those that do not are insoluble.



You will need:

safety glasses and laboratory coat
heatproof mat
7 test tubes
test-tube rack
spatula
samples of salt, sugar, flour, coffee, copper sulfate, sand and copper carbonate

- Half-fill each of the test tubes with cold water.
- Label the test tubes: salt, sugar, flour, coffee and so on.
- Use a spatula to add a very small amount of each substance to its labelled test tube. Do not use more than a quarter of a spatula full.
- Draw up a table of your results like this incomplete one:

Substance mixed with water	Clear or cloudy?	Solution? (yes/no)
Salt		
Sugar		
Flour		
Coffee		

- Hold each test tube up to the light. Decide whether the mixture is clear or cloudy. Record your results in the table.

Discussion

1. Which of the substances dissolved in water?
2. How can you tell if a substance has dissolved?
3. Read the information on *filtration* on page 173. Which of the mixtures could be separated by filtration?

HOW ABOUT THAT!

During World War II, scientists George de Hevesy and Niels Bohr had to hide two solid gold Nobel prize medals from the Germans who had just occupied their country, Denmark. They decided to place the medals in the only substance that is able to dissolve it — a mixture of hydrochloric and nitric acids called aqua regia. The resulting black mixture sat in plain sight for the rest of the war on a shelf in de Hevesy's laboratory. Afterwards, the gold was recovered from the solution and the medals recast and returned to their original winners.

5.3 Exercises: Understanding and inquiring

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 difference between a solution, a solvent and a solute.
2. Name the solvent and the solute in each of the following solutions.
   (a) Sea water
   (b) Soft drink
   (c) Coffee
3. **Identify** the solvent, solute and solution in this photo.



4. What leaves a fizzy drink to cause it to go flat?
5. What substance is added to cordial to make it more dilute?
6. **Describe** how an aqueous solution is different from other solutions.
7. What is the difference between a concentrated solution and a saturated solution?

Think

8. What colour do you think Coca Cola would be if caramel was not added? **Explain** your answer.
9. Why would you not expect to find a solution with a solid solvent?
10. You had a marker pen with waterproof ink in your shirt pocket but it has leaked everywhere! Suggest how you might remove the ink stain.
11. What substance should you add to salt water to make it
    (a) more concentrated or (b) less concentrated?

Investigate

12. Some substances dissolve better in hot water than in cold water. Design an experiment to compare the amount of sugar that can be dissolved in tap water that is cold and tap water that is hot.
13. It is claimed by manufacturers that some washing powders work just as well in cold water as in hot water. **Investigate** washing powders to find out whether they dissolve as well in cold water as they do in hot water.
14. Conduct a survey of food and drink products. Use the list of ingredients to determine what is in them. What are the most common chemicals added to food and drink products?
15. Design your own experiment to test whether a fizzy drink goes flat faster when it is cold or when it is warm. Remember to use a 'fair test'. You must keep everything the same except the one thing that you want to test.
16. Place an unopened can of soft drink and an unopened can of diet soft drink of the same type in a sink of water.
    (a) Which can floats?
    (b) Which can sinks?
    (c) What does this tell you about the sugar in soft drinks and diet soft drinks?

5.4 Mixing insoluble substances

5.4.1 Sneaky suspensions

Why have layers formed in this salad dressing?



Last week, you made a really nice salad dressing and it turned out just like the picture in the recipe book — a lovely, even, creamy, green-coloured liquid. Yum!

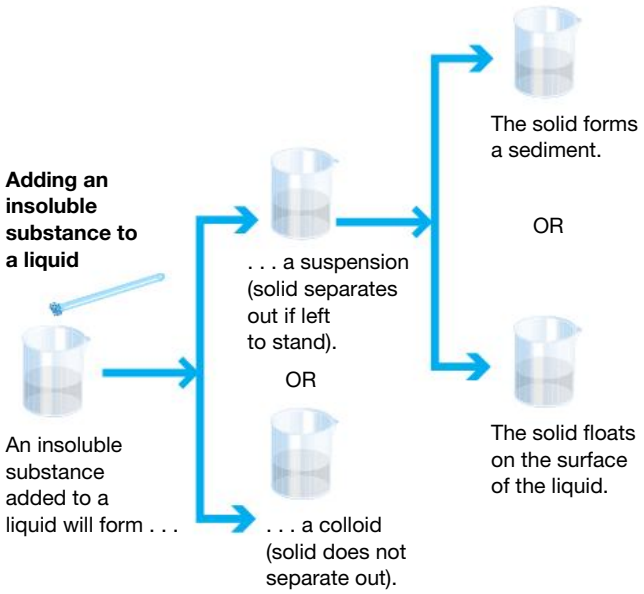
But now that you've gone to the fridge to get the salad dressing out to put on your lunch, it looks kind of odd. There seem to be two different layers of liquid in the bottle now — a dark browny-green layer on the bottom and a clear pale green layer on the top. What on Earth has happened to the dressing?

A solution is formed when a soluble substance (solute) dissolves in a solvent to form a **solution**. However, when insoluble substances are mixed, a different type of mixture is formed.

When an insoluble substance is added to a liquid and then stirred, particles of the undissolved substance are distributed throughout the liquid. What happens after that depends upon the size and density of the insoluble particles. If the solid separates from the liquid after a while, we say that the mixture is a **suspension**. If the solid particles have a very low density, they end up floating on the surface of the liquid. If the solid particles are large and dense, they sink to the bottom of the liquid to form a layer of **sediment**. For example, if you were to mix finely ground pepper and flour into water, you would find that the pepper, water and flour separate when left to stand; eventually, you would find that the pepper floats on the top of the clear water while the flour forms a thick white sediment on the bottom.

Olive oil is not soluble in vinegar. When brown vinegar and olive oil are mixed together vigorously, they form a creamy green salad dressing, which is a suspension. Over time, though, the two liquids will separate again, forming the layers you see in the photo above right, with the less dense olive oil floating on top of the more dense vinegar.

Some insoluble substances neither settle at the bottom nor float on the top of the substance they've been mixed into; instead, their particles remain spread throughout the liquid. These mixtures are called **colloids**.



5.4.2 Special types of mixtures

A colloid forms when the particles of one substance spread throughout another but do not settle out to form a sediment. Instead, the particles remain spread out. The substances that make up a colloid can have just about any state of matter. For example, a marshmallow is a colloid of a gas spread through a soft solid, hairspray is a liquid that spreads through a gas, and pumpkin soup is formed from solid lumps of pumpkin spread through liquid water. Even morning mist is a colloid formed by fine water droplets suspended in air.

Colloids that are made from liquids that spread evenly throughout each other and do not settle out are referred to as **emulsions**.

True emulsions are rare in nature. Many emulsions that we commonly see, such as homogenised milk and mayonnaise, are the result of industrial processes that bring together substances that, under normal circumstances, would separate out and look, feel or taste unappetising.

Unhomogenised milk has a layer of insoluble cream floating on the milk; homogenised milk is an emulsion.

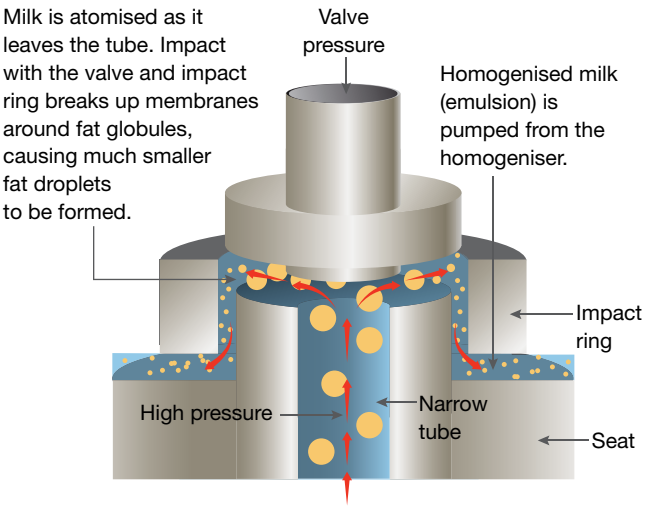


Homogenising milk

Milk straight from the cow is actually a suspension of large globs of creamy butterfat floating in the watery body of the milk. If left alone, the cream separates and floats to the top to form a cream layer. Dairy companies use a process called **homogenisation** to give the milk a smooth, creamy taste and a more even texture.

During homogenisation, the milk is forced at high pressure through tiny tubes in an **atomiser**. This destroys the membranes that surround the large butterfat globules, allowing the globules to be broken up into much tinier butterfat droplets. These much smaller droplets spread evenly throughout the watery part of the milk and are unable to clump together and settle out in a layer. The homogenised milk is an emulsion.

The homogenisation process

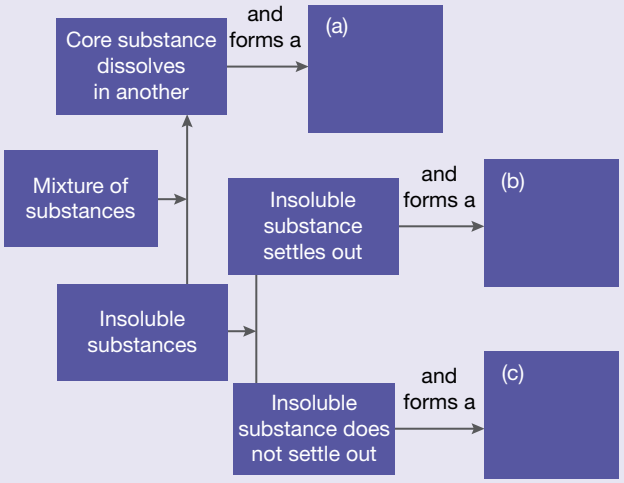


5.4 Exercises: Understanding and inquiring

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 single word that can replace each of the following expressions.
   (a) Liquid in which a substance dissolves
   (b) Insoluble particles that settle to the bottom of a liquid
   (c) Substance that dissolves in a liquid
   (d) Mixture that is formed when a solute dissolves in a solvent
   (e) Mixture in which the insoluble particles stay mixed throughout another substance
2. **Explain** how a colloid differs from a suspension.
3. Copy and complete the diagram opposite by placing the correct term in the lettered boxes.
4. How is homogenised milk different from fresh milk?



Think

5. Is smog a solution, suspension or colloid? **Explain** your answer.
6. Cream and butter are both made from milk. What types of mixture are cream and butter?
7. Many products contain chemicals called 'emulsifiers'. What do you think these chemicals do?

Investigate

8. Find out how skim milk, low-fat milk, condensed milk and evaporated milk are made. Which of these also undergo homogenisation?

Classify

9. In groups of three or four, decide whether the following substances are suspensions, solutions, colloids or combinations of these. Write down a reason for each decision. Share your results with the class.
   (a) Muddy water
   (b) Cup of coffee
   (c) Mayonnaise
   (d) Whipped cream
   (e) Hot chocolate
   (f) Cup of tea with tea leaves in it
10. Use the **'Time Out' mixtures** interactivity in the Resources tab to identify liquid mixtures. **int-0224**

learnON RESOURCES — ONLINE ONLY

Try out this interactivity: 'Time Out' mixtures (int-0224)

Complete this digital doc: Worksheet 5.1: Solutions and suspensions (doc-12378)

5.5 Separate ways

5.5.1 Decanting

There are a number of ways to separate undissolved substances from a liquid; you use many of these every day.

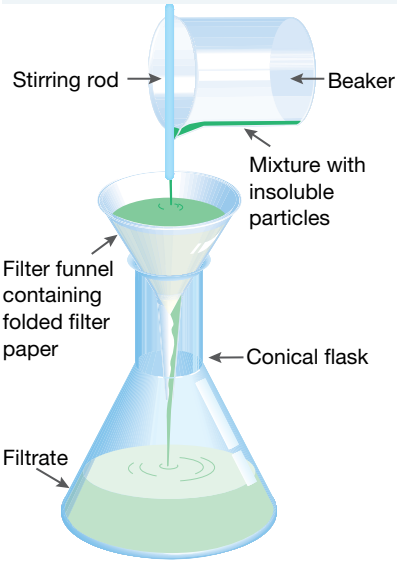
The simplest method of separating a mixture of a liquid and a sediment is called **decanting**. In this process, the mixture is poured into a container and, once the sediment settles to the bottom, the liquid is carefully poured off the top. You use the decanting method whenever you pour the hot water off cooked vegies for dinner!

5.5.2 Filtering

What do a vacuum cleaner, tea strainer and protective face mask have in common? They are all devices for separating mixtures by filtration. In the laboratory, filtration is done using filter paper, but there are many other useful methods of filtration that are used in the home and in industry. During filtration, solutions or gases pass through the filter but particles that cannot fit through the filter are trapped by it. Insoluble particles can be separated from a solution using filter paper in a funnel as shown on the right.

Indigenous Australians combine **sieving** (a type of filtration) and decanting to prepare native yams, which contain a poison. The yams are boiled and placed into a dilly bag. The bag is squashed and the softer parts of the yam are strained through the bag into a can of water. The bag acts as a sieve, allowing some substances to pass through but not others. The skins and harder parts of the yam that are left in the bag are thrown away. The water is decanted from the can, and repeated washing with water removes more poison. The yam is then placed into another dilly bag and hung up overnight before being ready to eat.

Equipment used to filter a mixture that contains insoluble particles



INVESTIGATION 5.3

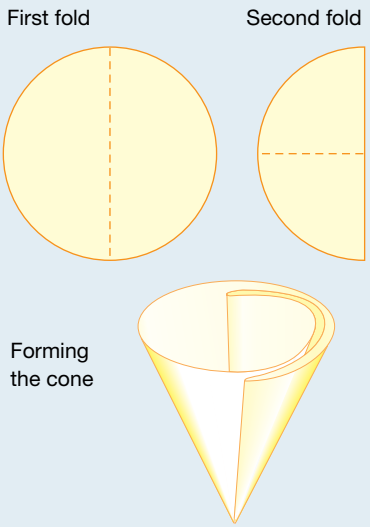
Filtration in the laboratory

AIM: To investigate filtration

You will need:
100 mL beaker
filter paper
glass stirring rod
insoluble substance, such as soil, chalk dust, charcoal
funnel
conical flask

- Half-fill your 100 mL beaker with water.
- Add your insoluble substance to the water and stir with the stirring rod.
- Set up the equipment for filtering as shown in the diagram above.
- Fold the filter paper as shown in the diagram at right.
- Place the filter paper in the funnel and moisten with clean water to hold the filter paper in place.
- Pour your mixture into the filter paper.

Folding filter paper



Discussion

1. Describe the appearance of your mixture in the beaker before filtration. Did it form a suspension or sediment, or float on top?
2. The liquid passing through the filter into the conical flask is called the *filtrate*. Describe your filtrate.
3. Examine your filter paper. The material trapped by the filter paper is called the *residue*. Describe your residue.
4. Filter paper is like a sieve with small holes in it. Explain how the filter paper worked like a sieve in this experiment.

5.5.3 Separating funnel

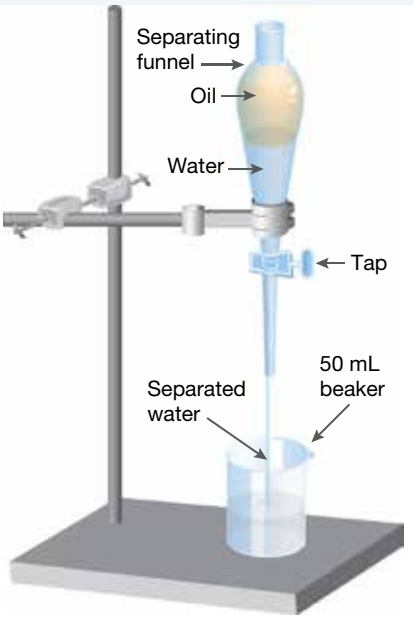
When one liquid does not mix with another but floats on top of it, a **separating funnel** can be used to separate the two liquids. Oil floats on water. This mixture can be separated using a separating funnel as shown at the top of the next page. By turning the tap, the lower liquid layer can be drained.

5.5.4 A dirty problem

On 20 April 2010, an explosion on the BP Deepwater Horizon drilling rig caused a massive oil spill into the waters of the Gulf of Mexico. By the time the leak was capped nearly three months later, thousands of square kilometres of ocean were covered with a layer of oil. Oil spills such as this have a tremendous impact on the marine and coastal environment as well as the local economy. In order to minimise the effects of an oil spill, the oil itself had to be separated from the water as quickly as possible.

Separating liquid suspensions can be done in the laboratory by using a separating funnel. But when you have an oil slick that is hundreds of square kilometres in size floating on the surface of the ocean, you obviously can't use a separating funnel to clean up the oil. Instead, oil slicks can be separated from water by considering some of the different properties of oil and sea water.

Using a separating funnel to separate oil from water



How to clean up an oil spill!

Biodegradation of the oil occurs when micro-organisms in the ocean break the oil down to use as a source of nutrients. This removes the oil from the water naturally. However, this process may take many years.

Oil spill dispersants can be sprayed onto the oil by helicopters, planes or boats. Dispersants contain substances called **surfactants** that can break up the oil into much smaller droplets. The detergent that you use to break up the grease on your dishes is also a surfactant. The smaller oil droplets are then more easily broken down by bacteria, algae and decomposers in the ocean.

As oil is **flammable** but water is not, the oil can be removed from the water by burning it off the water surface. The oil is ignited by a **helitorch**, which is lowered to the spill surface from a helicopter. However, while fresh crude oil burns well, oil that has been on the surface of the water for a while becomes **weathered** and is harder to ignite. Also, if a spill has spread too far, the oil layer may have become too thin to ignite. The smoke produced from burning the oil can cause pollutants and toxins to enter the air.

Biostimulants can be added to the ocean. These are chemicals, such as fertilisers, that increase the numbers of micro-organisms in the ocean and so speed up the rate of biodegradation of the oil.

Booms are used to control the spread of oil. These float on the ocean surface and extend down into the water below the level of the oil. Booms are made of **buoyant** materials such as neoprene.

Skimmers are dragged by boats across the top of the oil spill and scrape the oil from the water surface. The oil is then sucked into storage tanks on board the boats.

HOW ABOUT THAT!

The tea bag was invented quite by accident by a tea merchant called Thomas Sullivan in about 1903. To cut costs, he sent customers his tea samples in small silk bags rather than a much larger sample of loose leaf tea.

Rather than opening the bags to put the tea in their pots, many customers found that if they left the tea in the bag they didn't have` to strain out the tea leaves. Nowadays, paper is used instead of silk and Tetley sells over 200 million teabags a week!

A teabag is a simple filter.



5.5.5 Centrifuging

A mixture can be separated by spinning it very quickly. This method is called **centrifuging**. The spin-dry cycle of a washing machine acts as a centrifuge and a filter. As it spins at high speed, the clothes are forced to the sides of the tub and the water passes out through the holes in the tub. The clothes cannot fit through the holes and so much of the water is removed from them.

In the laboratory, centrifuging is used to separate solid or liquid substances from liquids. The mixture is placed in special test tubes that are spun in a circle at high speeds. The heavier substances are forced to the bottom of the tube and the lighter substances are left near the top.

INVESTIGATION 5.4

Using a centrifuge (teacher demonstration)

AIM: To investigate separation using a centrifuge

You will need:
centrifuge
mixture containing iron oxide, lead oxide (red lead) and water

CAUTION: Use red lead in a well-ventilated room. Avoid contact with skin and eyes. Do not dispose of down the sink.

- Stir the mixture and then pour equal amounts into two separate centrifuge test tubes.
- Put the test tubes on opposite sides of the centrifuge.
- Allow the centrifuge to spin for about a minute.
- Observe the mixture after centrifuging.

Discussion

1. Describe the mixture after centrifuging.
2. Why must the test tubes be placed on opposite sides of the centrifuge?
3. Could the separated substances form a mixture again? Explain your answer.
4. What type of mixture was the iron oxide, lead oxide and water before centrifuging?

5.5 Exercises: Understanding and inquiring

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. When filtration separates a mixture of muddy water, **identify** which part is the
   (a) filtrate (b) residue.
2. **Recall** what happens to a suspension if it is left to stand for a long time.
3. **Recall** which method of separation uses spinning to separate the parts of a mixture.

4. Why is it important to clean up oil spills from the ocean?
5. What is biodegradation?
6. **Explain** how skimmers and booms can be used to control and collect oil from the ocean surface.

Think

7. **Describe** the properties of water and dirt that make them ideal to separate using filtration.
8. **Describe** the properties of tea leaves and water that make them ideal to separate by centrifuging.
9. Early settlers would spin the billy three times in an anticlockwise direction before drinking their tea. Would it make any difference if the billy was spun in a clockwise direction? **Explain** your answer.
10. During filtration, **explain** why it is important that the mixture is poured carefully.
11. The air filter and oil filter in a car engine have to be replaced occasionally. Why do you think this is done?
12. Which of the methods of removing spilled oil from water allow the oil to be recovered for use?
13. If micro-organisms in the ocean break down the oil from oil spills, why do we use other oil removal methods such as burning and skimming?

Imagine

14. You are out in the bush and the only water available to drink is in a muddy waterhole. You have an empty bottle and a cup. How would you remove the dirt from the muddy water so that you could drink the water?

Create

15. Make your own billy tea. Instead of centrifuging the tea, use another method to separate the tea leaves from the tea. Write down your method for separating out the tea leaves. Was it an effective method? **Explain** your answer.

Investigate

16. The kidneys act as filters to remove wastes from our blood. Find out more about how the kidneys filter wastes from the blood.
17. What types of paper can be used to filter a suspension? Carry out an investigation that tests a variety of different papers (such as newsprint, tissue paper, brown paper and kitchen towel) for their suitability as filter paper. Write a report on your findings.
18. Use the **Filtration** interactivity in the Resources tab to identify mixtures that can be separated by filtration. **int-0223**

learnON RESOURCES — ONLINE ONLY

Watch this eLesson: Centrifuging (eles-0061)

Complete this digital doc: Worksheet 5.2: Filtration (doc-12379)

Try out this interactivity: Filtration (int-0223)

5.6 Separating blood

Science as a human endeavour

5.6.1 The blood mixture

About one million donations of blood are made in Australia each year (see page 178). Some of the donations are given to people who have lost blood during surgery, accidents or disasters. Blood is also given to people during the treatment of many diseases, including cancer. These people need to be given a regular supply of blood.

Blood is a life-giving mixture. It can be separated into four parts: **plasma**, a clear, yellowish liquid; **red blood cells**, which carry oxygen; **white blood cells**, which fight disease; and **platelets**, which clot blood.

Because each part of the blood has a special job to do in our bodies, different problems can be treated with different parts of the blood. In Australia, blood is collected and separated by the Australian Red Cross Blood Service. **Separation** allows doctors to treat a larger number of patients and save many lives.

Not all donations are of whole blood. Depending on their blood type, people may be asked to donate just plasma or platelets.

5.6.2 Separating by centrifuging

The parts that make up the blood mixture have different properties; the red and white blood cells are heavier than the plasma and platelets. The difference in the mass of these parts means that they can be separated using the process of centrifuging. Centrifuging involves spinning the mixture very quickly. The heavier parts of the mixture are forced to the outer edge of the centrifuge. The lighter parts can then be decanted from the heavier parts.

Blood type	Percentage of population	Most useful donations	Main uses
AB	3%	Plasma	AB plasma can be given to any blood type.
A	38%	Whole blood, plasma or platelets	Common blood type so high demand for these products
B	10%	Plasma	Particularly useful for people with blood diseases, severe burns or trauma
O–	9%	Whole blood or platelets	All products can be given to any blood type.
O+	40%	Whole blood, plasma or platelets	Most common blood type; high demand for these products

HOW ABOUT THAT!

The amount of blood in your body depends on how much you weigh. The blood volume of an adult of average weight is about 5 litres, so the standard donation of 470 mL is less than 10 per cent of the donor's total blood volume. This amount is easily replenished by the body. To help avoid fainting during or after a donation, you must be over 18 and weigh more than 50 kg to be a blood donor.

5.6 Exercises: Understanding and inquiring

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 blood is separated into different parts.
2. **Recall** why blood clots do not form in a blood donation.
3. **Identify** which technique is used to separate the different parts of blood.
4. **Describe** which separation technique is used to separate red and white blood cells.

Think

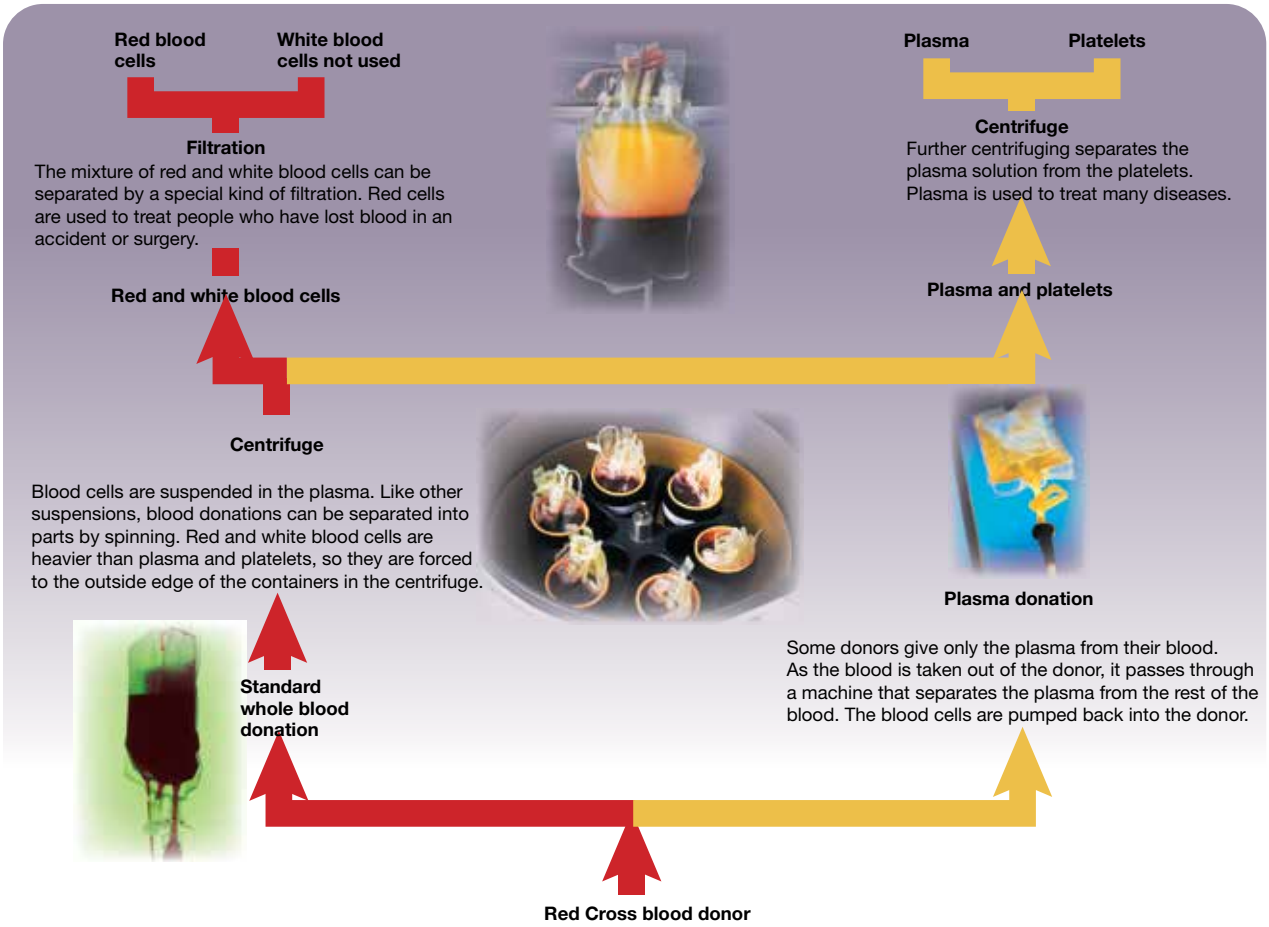
5. **Explain** why blood is separated in a centrifuge rather than left to settle by itself.
6. **Deduce** what property of plasma and platelets allows them to be separated with a centrifuge.

Create

7. Create and **construct** an advertisement to encourage people to donate blood. The advertisement could be in the form of a poster, a song, a set of digital photos or part of a multimedia presentation.

Research

8. **Investigate** the following facts about blood donation:
   (a) how old you need to be to donate blood
   (b) the minimum weight blood donors must be
   (c) why you cannot donate blood if you have recently had a tattoo done.



Once blood is separated, each part has to be stored differently.

- Red blood cells can be stored for 42 days at 2–6 °C.
- Plasma can be frozen for 12 months at –40 °C.
- Platelets are stored for 5 days at 20–24 °C. During this time they have to be moved at least every 12 hours to stop them clumping. (Platelets seal wounds in our bodies by sticking together.)



HOW ABOUT THAT!

In a normal week, the Australian Red Cross Blood Service needs about 21 000 blood donations to meet the demand for blood and blood products. Public holidays put a strain on the blood service, with fewer working days in the week to take that number of donations. The demand for blood is also likely to increase, due to the increase in road crashes that can occur on long weekends.

5.7 Separating solutions

5.7.1 Distillation

Separating undissolved substances from a liquid is relatively easy compared with separating out substances that have been dissolved into a solution. In order to do this, you need to make use of the fact that the solute and the solvent have different chemical and physical properties.

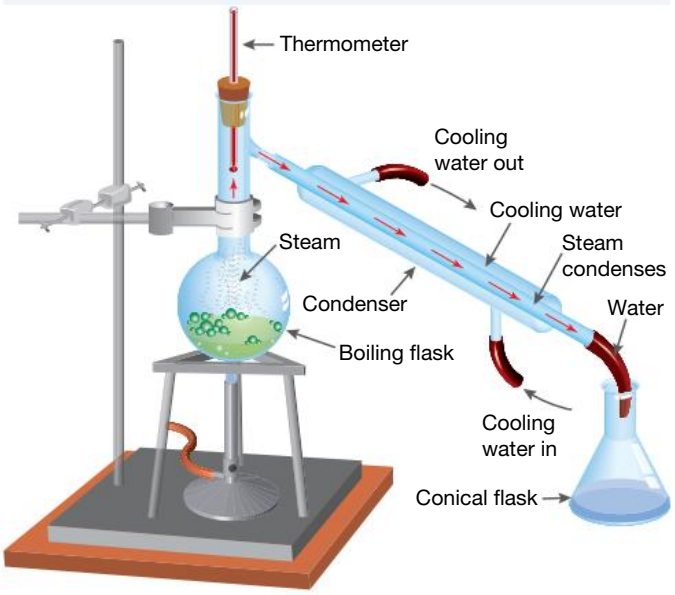
Some laboratory experiments require the use of pure water rather than tap water, which contains many different impurities such as chlorine, fluoride, magnesium, calcium and sodium. However, pure water can be separated from tap water by a process called **distillation**. The process of distillation can be used when the substances to be separated have different boiling points.

Distilling water

As you can see in the diagram below, tap water is placed in the boiling flask and heated to the boiling temperature for water, 100 °C. The water boils, **evaporates** and becomes steam. The impurities from the tap water have a higher boiling point than the water and so they remain behind in the boiling flask. The steam travels along the **water condenser**. The steam inside the condenser is cooled to below 100 °C and **condenses** to form liquid water. The condenser is kept cool by running cold water through its outer jacket. The pure water collected in the conical flask is called the **distillate** and can be rightly labelled **distilled water**.

The distillation process is also used to isolate pure essences from plant and animal sources for the perfume industry, to get fresh water from sea water and, on a much larger scale, to separate petrochemical products such as petrol and paraffin from crude oil.

Equipment used for distillation in the laboratory



5.7.2 Evaporation

Evaporation works in a similar way to the distillation process, except that evaporation does not require the solution to reach boiling point. Instead, the water particles absorb a smaller amount of heat energy over a longer period of time; when they have absorbed enough energy, they form water vapour.

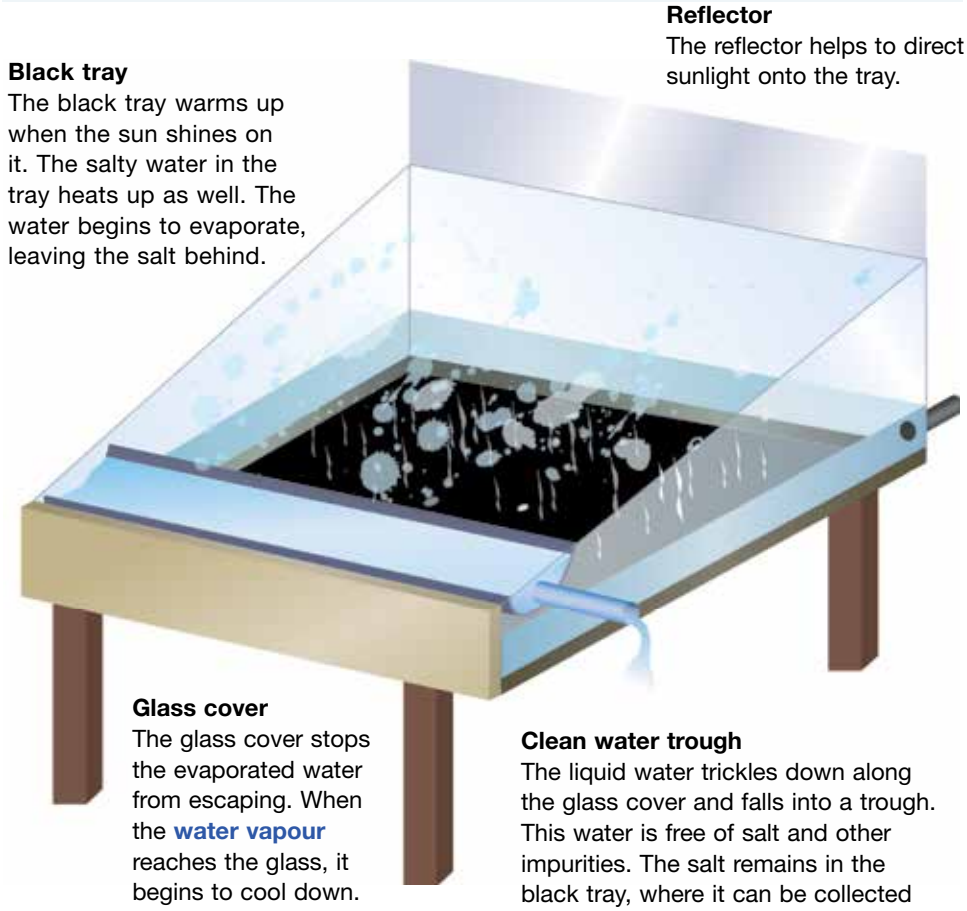
Solar distillation

In places where fresh water is scarce, the evaporation method is used in the form of **water stills** to turn salty or otherwise undrinkable water into a purer drinkable form. Water stills heat the impure water solution to the point where the pure water evaporates from the mixture, leaving behind salt and other impurities. The chief advantage of the evaporation method of purifying water is that it can be done with very simple equipment.

The salt that encrusts Lake Eyre was originally left behind 30 000 years ago when the sea water in it evaporated away.



Equipment for solar distillation



Reflector
The reflector helps to direct sunlight onto the tray.

Black tray
The black tray warms up when the sun shines on it. The salty water in the tray heats up as well. The water begins to evaporate, leaving the salt behind.

Glass cover
The glass cover stops the evaporated water from escaping. When the **water vapour** reaches the glass, it begins to cool down. The vapour turns back into liquid water.

Clean water trough
The liquid water trickles down along the glass cover and falls into a trough. This water is free of salt and other impurities. The salt remains in the black tray, where it can be collected and used for other purposes.

5.7.3 Desalination plants

The processes of distillation and evaporation are not suitable for purifying sea water on a scale large enough to supply drinking water to large communities. Several Australian states have built desalination plants in an effort to increase the supply of drinking water to their capital cities. These plants use a process called **reverse osmosis** to separate salt from large quantities of sea water. This involves passing sea water under very high pressure through thin membranes wound in coils. The membranes have very tiny holes in them that allow water through without the salt.

The use of desalination plants is controversial. Two major concerns are that:

- they use a lot of energy, which is supplied by coal-fired power plants. Apart from the pollution caused by these plants, many people feel that they are not **sustainable**; that is, they cannot continue to operate without putting the environment and our future at risk.
- the water flowing back to the sea contains much more salt than normal sea water. It is also warmer. This can affect marine animals and plants that live near the desalination plant.

INVESTIGATION 5.5

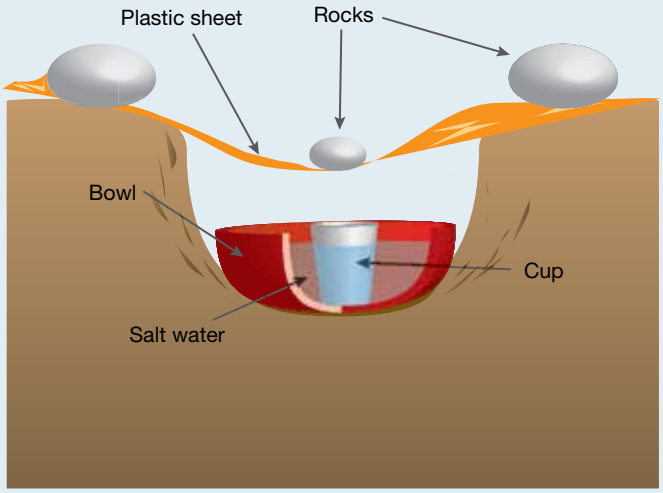
Making a simple water still

AIM: To investigate solar distillation

You will need:

trowel
cup
bowl
salt water solution
scissors
plastic bag
some small stones

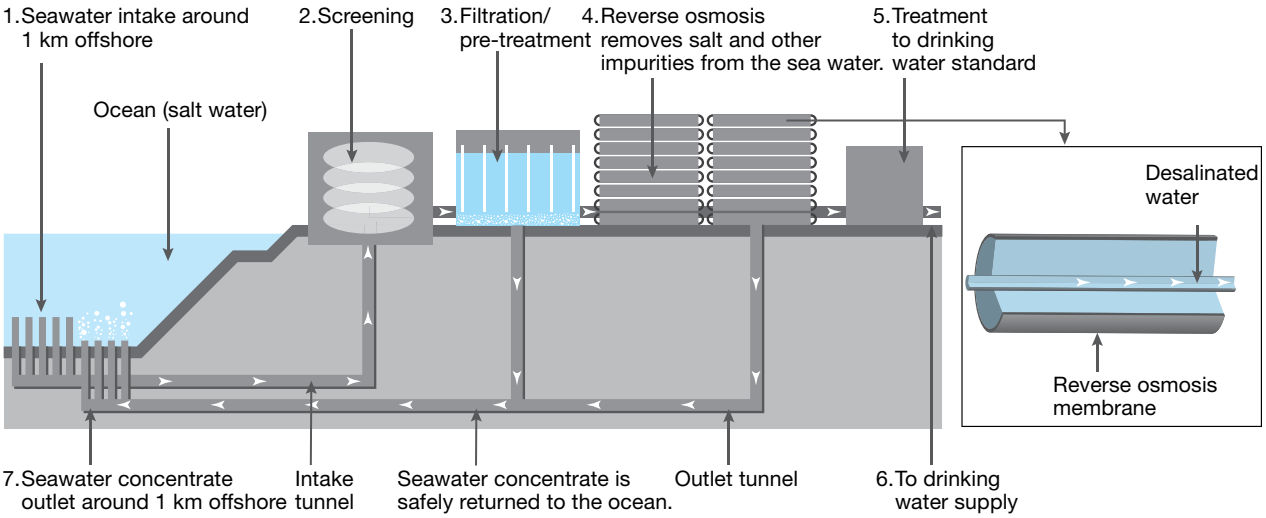
- Dig a shallow hole in the ground outside. The hole should be a few centimetres deeper than the height of the cup and should be in a spot that gets a lot of sun.
- Put the bowl in the bottom of the hole and put the cup in the middle of the bowl.
- Pour the salt water into the bowl. Don't allow any to get into the cup.
- Cut the side seams of the plastic bag and open it up so that it forms a flat sheet of plastic. Place the plastic over the hole, using small rocks to anchor it in place. Make sure that the hole is completely covered.
- Place a small stone in the middle of the plastic sheet, just above the mouth of the cup.
- Leave undisturbed for a couple of hours then examine the contents of the bowl and the cup.



Discussion

1. How has the water level in the bowl changed?
2. Is there any residue on the walls of the bowl? What do you expect this is made of?
3. How is the water in the cup different from the water in the bowl? You may need to taste it to tell the difference — check with your teacher first!

Typical desalination plant



5.7.4 Crystallisation

In *Investigation 5.5*, you may have found very small salt crystals on the wall of the bowl. This is the solute left behind when the solvent (water) evaporated from the salt water solution. **Crystallisation** occurs when the solvent is removed slowly enough from the solution that the remaining solute particles have the time and mobility to arrange themselves into regularly arranged structures, which we call crystals. The crystals formed by different solutes vary widely in shape. In fact many substances in nature can be identified just by considering the shape of the crystals that they form.

Crystallisation is used if it is more important to collect the solute than the solvent, as the solvent is usually lost to the atmosphere during this process and not collected. Many important pharmaceutical products are purified using this process.

INVESTIGATION 5.6

Fun with crystals

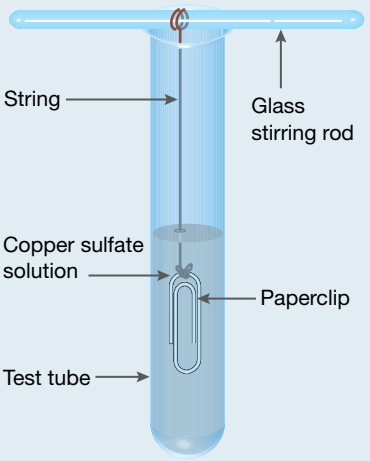
AIM: To investigate crystallisation

This activity must be done in class with your teacher.

You will need:

2 test tubes
solid copper sulfate (or alum)
a balance
150 mL beaker
3 glass stirring rods
hot water
string
test-tube rack
forceps
microscope (optional)
piece of filter
paper
filter funnel
conical flask or beaker
2 paperclips

- Weigh 28 g of the copper sulfate in the beaker.
- Prepare a hot concentrated solution of the copper sulfate by pouring 20 mL of hot water into the beaker. Stir the solution until no more solid will dissolve.
- Pour the blue copper sulfate solution through the filter paper into the conical flask or beaker. The undissolved copper sulfate will remain on the paper.
- Quickly pour equal volumes of the solution into two test tubes. Cool one test tube by putting it under cold running water.
- Tie the string to the glass rod. Attach the paperclip to the end of the string and arrange it as shown right. Do the same for the other test tube.
- Leave both test tubes to cool overnight in the test-tube rack.
- Remove some crystals using forceps.
- You may wish to view the crystals under a microscope.
- Crystals with interesting shapes can also be made using alum (potassium aluminium sulfate).



Discussion

1. What can you see in the test tubes?
2. Is there any difference in the size of the crystals between the two test tubes?
3. How could you make bigger crystals?

5.7.5 Chromatography

Paints, inks, dyes and food colourings are often mixtures of substances that have different colours. You can separate a mixture of different colours using **paper chromatography**.

In paper chromatography, a liquid soaks through the paper and carries the mixture with it. Some substances in the mixture are carried through the paper faster than others. In this way, the substances in the mixture are separated along the paper.

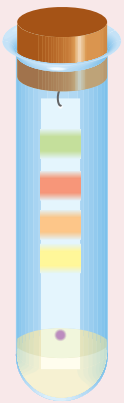
Chromatography works because different colours have different **solubilities**. Some colours dissolve more easily than others. Water is a very good solvent for many food colours. However, to separate the colours, they are not all placed straight into the water. For paper chromatography, the food colouring is placed on paper just above the solvent. The colours dissolve as the solvent soaks up the paper column. The colours separate because they are washed along the paper at different rates. The less soluble colours move more slowly and travel less distance up the paper. More soluble colours move more quickly up the paper.

How chromatography works

Separated colours
The colours that dissolve more easily are carried further up the filter paper by the solvent. The colours become separated along the paper strip.

Sample of food-colour mixture
A small amount of food colour is placed on the paper, above the level of the solvent.

Solvent
The filter paper is hung so that it just dips into the solvent. The solvent soaks up the strip of filter paper, taking the food colours with it.



A chromatograph automatically separates mixtures by chromatography.



INVESTIGATION 5.7

Separating colours

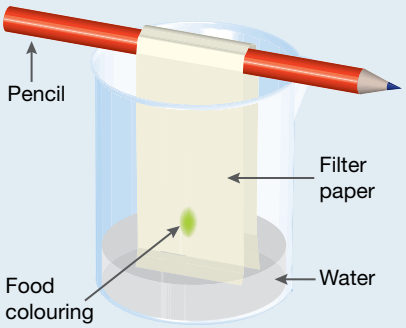
AIM: To investigate paper chromatography

You will need:
food colouring
filter paper
250 mL beaker
ruler
toothpick
scissors
pencil

- Cut a piece of filter paper approximately 10 cm by 3 cm.
- Rule a pencil line 2 cm from the end of the paper.
- Use the flat end of a toothpick to place a small dot of food colouring in the centre of the pencil line on the filter paper.
- Pour tap water into the beaker to a depth of 1 cm.
- Stand the filter paper so that the end just dips into the water (see diagram at right). Make sure that you keep the dot of food colouring out of the water.
- Fix the filter paper to a pencil to hold it in the beaker.
- Leave the filter paper to stand until the water has risen almost to the end near the pencil.
- Repeat the experiment with different food colourings.

Each one of the food colourings that cover these chocolates is a mixture of different colours. How can the different colours be separated?



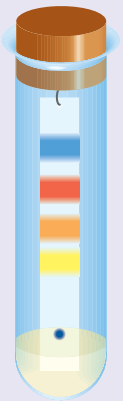


Discussion

1. What colours were in the first food colouring tested?
2. How do you think the colours are actually separated using this method?
3. List the different food colourings that you tested. For each one, write down the colours that made up the food colouring.

5.7 Exercises: Understanding and inquiring

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** which methods of separation can be used to separate the parts of a solution.
2. **Explain** the purpose of the glass cover on a solar water still.
3. **Recall** why water is used as a solvent to separate food colours.
4. **Identify** the colours found in this ink, from:
   (a) the fastest moving to the slowest moving
   (b) the most soluble to the least soluble.
5. The building of desalination plants is controversial. List two reasons for this.

Think

6. **Describe** the difference in properties that distillation relies on.
7. **Explain** why crystallisation would not be suitable for purifying water.
8. **Deduce** why cool running water is passed through distillation equipment.
9. **Explain** why the mixture is placed above the level of the solvent in chromatography. (*Hint:* What would happen if the mixture was put in the solvent?)
10. Zoe performs a chromatography experiment on waterproof markers using water as a solvent. Will her experiment work? **Explain** your answer.

Using data

11. The table below shows the composition of the substances dissolved in one litre of sea water.

Substance	Amount (g)
Chlorine	19
Sodium	11
Sulfate	3
Magnesium	1.5
Calcium	0.5
Potassium	0.5

(a) Use this information to draw a bar graph, with the substance names on the horizontal axis and the amount (in g) on the vertical axis.
(b) Approximately how many grams of solute are in each litre of sea water?
(c) It is common for ships to have their own distillation equipment allowing pure drinking water to be produced from sea water. If no water is lost during the process, how much pure water could be provided from one litre of sea water? (*Note:* One litre of sea water weighs 1020 grams.)

Design and create

12. Use chromatography to create colourful designs that can be displayed as scientific art. Fold the filter paper and use different colours to make your designs unique.
13. Design and build a separating machine that separates a mixture of three substances. Create a brochure to advertise your separating machine, including
    (a) the name of your separating machine
    (b) a diagram of the machine
    (c) information on what mixture your machine will separate
    (d) instructions for using it
    (e) an explanation of why it works
    (f) the advantages that your machine has for its particular use.

Investigate

14. **Investigate** how to distil perfume.
15. **Investigate** different types of solvents that could be used to separate pen ink and ink from waterproof markers. Before running the experiment, have your choice of solvents approved by your teacher. As a starting point, you may wish to use methylated spirits.
16. Does the colour of food affect whether people choose to buy and eat it? **Design** an experiment to test your answer.
17. The crystal shown at right is called a hopper crystal. Use the library and the internet to find out:
    (a) what substance the crystal is made from
    (b) why hopper crystals rarely form in nature
    (c) how these crystals are formed.



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Watch this eLesson: Distillation (eles-0060)

Complete this digital doc: Worksheet 5.3: Distillation (doc-12380)

Complete this digital doc: Worksheet 5.4: Evaporation and crystallisation (doc-12381)

Complete this digital doc: Worksheet 5.5: Chromatography (doc-12382)

5.8 Down the S-bend

Science as a human endeavour

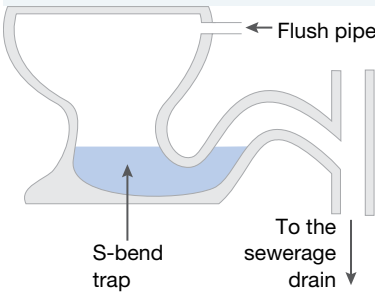
5.8.1 What happens to waste water?

Every time you flush the toilet, have a shower, wash the dishes or your clothes or even clean your teeth, the waste water travels into an underground **sewerage** drain.

The waste water is a mixture of human body waste flushed down the toilet, and detergent, dirt, toothpaste, food scraps and other materials washed down the drains. The mixture, which is mostly water, is called **sewage**.

If you live in a major city, the sewage in the drain under your house flows into a larger drain under your street and travels through the sewerage system to a treatment plant. The waste water needs to be treated before it can be returned to the **environment**.

The S-bend trap in the toilet fills with clean water to prevent smelly gases from the sewer travelling back into the house.



Sydney is presently serviced by 31 sewage treatment plants, which are located along the coast and inland. The three largest coastal plants at Bondi, Malabar and North Head process three-quarters of the city's sewage. Between them, they process nearly 1 billion litres of waste water every day! Of this, over 35 million litres of water is recycled. All of the collected biosolids are treated and then turned over for agricultural use, mostly as fertiliser, and the remaining treated waste water is piped 3 kilometres or so offshore where it is emptied deep in the ocean.

In country centres, treatment plants are usually located on the edge of the town. These plants may discharge treated water into nearby rivers. If there is no local treatment plant, the waste water will flow into a personal sewage treatment system — a **septic tank** buried in the backyard.

A septic tank contains **bacteria** that break down the sewage. A thick, smelly sludge is formed. The sludge sinks to the bottom of the tank and clear water flows out into the surrounding area. The sludge needs to be removed from time to time.

5.8.2 Waste water treatment

Waste water contains **suspended** solids, such as bacteria, grit and dirt, as well as some large items like rags and sticks. It also contains many dissolved substances.

When the waste water arrives at the sewage treatment plant, it passes through a screen (a wire mesh **filter**) that removes the larger items. The sewage then flows into settling tanks where it is kept for about two hours. In the settling tanks, suspended solids settle to form a sediment, and **floatables** such as oil and plastic collect on top of the sewage and are removed.

The watery part of the sewage flows from the settling tank into secondary treatment. This waste water still contains dissolved substances and bacteria. Secondary treatment takes place by filtering the water though soil and grass or by storing it in a series of one-metre-deep lagoons for two to four months. In the secondary treatment, the bacteria in the waste water break down the dissolved substances to purify

the water further. In the lagoons, sedimentation also takes place. The treated water looks clear but it is still not safe to drink.

The Tank Stream was Sydney's first water supply. It still flows beneath the city's streets.



5.8.3 Think first!

There are many materials that should not be tipped down kitchen, bathroom, laundry or school laboratory sinks. The treated water is eventually released into the sea, but there are many substances that the sewerage system is not designed to treat.

These substances include:

- chemicals such as oven cleaners and insect sprays that are poisonous
- substances like fat and oil that don't dissolve in water.

These substances can eventually find their way to the sea, polluting it and killing or harming animals, plants and other living things (like algae) that live there. Substances like these should be saved for collection by local councils.

Small objects like cotton buds and tampons should not be flushed down the toilet because they can block the filters at treatment plants. These objects can be put out with other household garbage.

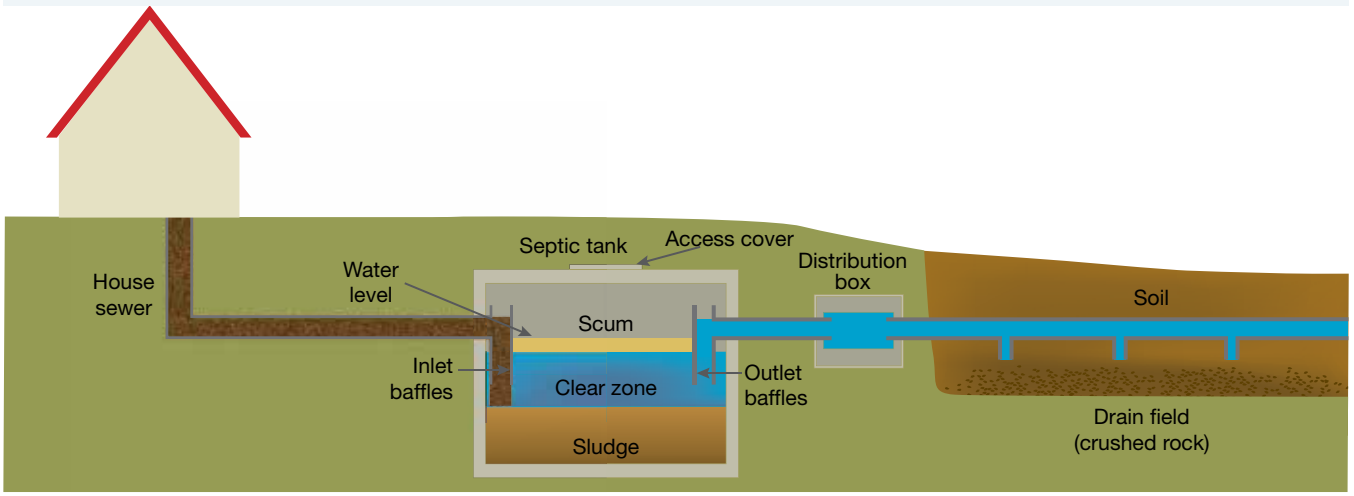
Play it safe

The best policy at home is to avoid putting down the sink anything solid or oily, or that you suspect may be poisonous or harmful to living things. Some things that can go down the sink at home in small amounts are:

- drain cleaners
- window cleaners
- kitchen and bathroom cleaners
- disinfectants (unless you have a septic tank).

At school, you should not tip anything down the sink except water, unless your teacher instructs you to.

A typical septic tank system



5.8 Exercises: Understanding and inquiring

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Remember

1. **Recall** what substances are found in waste water.
2. **Explain** how a septic system works.
3. **Identify** substances that should not be tipped down the kitchen sink.

Think

4. **Propose** why disinfectants that kill bacteria cannot be poured down a septic system.
5. A certain type of shower provides water at a rate of 11 litres per minute.
   (a) If you have a five-minute shower, **calculate** how much water you would use.
   (b) **Calculate** how much water you would use showering in a year.
   (c) **Calculate** how much water your family would use showering in a year.
6. (a) Make a list of the many ways that people use water in their homes.
   (b) **Propose** ways to reduce water usage.

Investigate

7. **Investigate** where your sewage goes. If you live in the country, ask your local shire or locate your septic system.
8. Find out the kind of treatment (primary or secondary) that is used for Sydney's sewerage system. Where does the treated water go? **Assess** how suitable this system is for a large city like Sydney.
9. Find out more about the Tank Stream that runs below Sydney. What might be the difference between today's water supplies and those of Old Sydney?
10. **Investigate** who is responsible in your area for the collection of waste that cannot be tipped down the kitchen, bathroom or laundry sinks, and how often it is collected.

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Watch this eLesson: Treating sewage (eles-0059)

5.9 Fit to drink?

Science as a human endeavour

5.9.1 Unwanted substances

Water used for drinking and washing needs to be clean and free of harmful substances. Water supplies can be **contaminated** by dissolved substances or substances suspended in the water. Besides clay, there are a number of other contaminants.

- Human and other animal body wastes contain disease-causing micro-organisms.
- Algal blooms can release poisonous substances into the water. They can also affect the taste and cause odour problems.
- Pesticides and detergents can be washed into rivers and contaminate water supplies.
- Poisonous chemicals may also be washed into rivers.
- Salt dissolved in water can make it unfit for drinking.
- Iron dissolved in water can contaminate it. This is common in bore water.
- High levels of calcium and magnesium salts can cause water to be 'hard', making it difficult to lather. This causes problems in laundries, bathrooms and kitchens.

5.9.2 Tap water

The tap water that we drink may be slightly alkaline (the opposite of an acid) because of the chemicals that have been added to it during the filtration process or that have leached into it from the pipe systems being used. A litre of tap water can contain as much as 150 milligrams of undissolved solids and, on average, 20 mg of calcium, 5 mg of magnesium, 1 mg of fluoride, 10–20 mg of sodium and a lot of other inorganic chemicals, all of which contribute to making Sydney's water much harder than tank water.

However, many of these chemicals are there for a good reason! The calcium in the water supply is mainly in the form of a compound called **lime**. Lime is added to balance the **acidity** of the water caused by adding chlorine and fluoride.

A litre of water also contains about 0.8 mg of **chlorine** and between 0.05 and 1.45 mg of **monochloramine**. These are disinfectants that are used to kill any dangerous bacteria or micro-organisms that may enter the water supply. The amount of disinfectant added to the water varies widely depending on a number of factors. For example, in summer, the warmer water tends to allow bacteria and microbes to increase faster, so more disinfectant is added to kill them. **Fluoride** is also added to help prevent **tooth decay**.

5.9.3 Would you drink this water?

Would you like your water to come out of the tap looking like this? Would you bathe or shower in it? Imagine your clothes after washing them!

The cloudiness of the muddy water is caused by tiny clay particles. Muddy water is an example of a colloid. A colloid is a cloudy mixture that contains suspended particles too small to be removed by filtering.

Untreated water straight from a water supply such as a dam can be cloudy and contain many dissolved and undissolved particles. It must be treated before it reaches your house.



Country water supplies

If you live in a country town, your water probably comes from a nearby river or lake. It is quite likely you would not want to drink that water unless it had been purified. Many country towns have their own water treatment plants. Water is pumped from the river or lake into the treatment plant. The cloudy water contains mud and other substances in suspension, which can be settled out of the water by a process called **flocculation**.

The suspended particles would take a long time to settle if the water were just left standing, and so the chemical **alum** (potassium aluminium sulfate) is added to the cloudy water to make the small particles clump together. These clumps are called **floc**. The floc is heavy enough to settle to the bottom of the tank and form a sediment. The water above the sediment is clear and flows off to the filtering stage.

After flocculation, the clear water is filtered through sand and gravel to remove any leftover suspended substances in the water. Chlorine is added to kill harmful bacteria. The purified water is then pumped to the local water tower, which then supplies the town with drinking water.

5.9.4 Blackwater and greywater

About 20 per cent of the waste water from an average household comes from the toilet. This waste water is known as **blackwater**. The rest of the waste water, known as **greywater**, comes from the kitchen, bathroom and laundry and does not flow into the sewerage system or septic tanks.

Greywater from the laundry can be used on the garden. However, it contains chemicals left over from detergents and other laundry products that could cause damage to plants. Damage can be minimised by selecting detergents that are low in phosphorus and **biodegradable**. Untreated greywater from the kitchen should never be used on gardens because it contains oil, grease and other chemicals that could damage plants.

The safest way to use greywater is to install a greywater treatment system, which removes chemicals that will damage plants. In some locations a council permit is required for the installation of a greywater treatment system, so it is important to check first. Untreated blackwater should never be used on a garden.

A reedbed can be used to treat greywater. Greywater is filtered in a tank filled with layers of sand and gravel; this removes some solids. The water then leaves the bottom of the tank and flows into a reedbed or miniature wetland. Reeds or other plants help to absorb nutrients such as nitrogen and phosphorus, and also take up some of the water.

A reedbed is one way of treating greywater.



INVESTIGATION 5.8

Treating your own dirty water

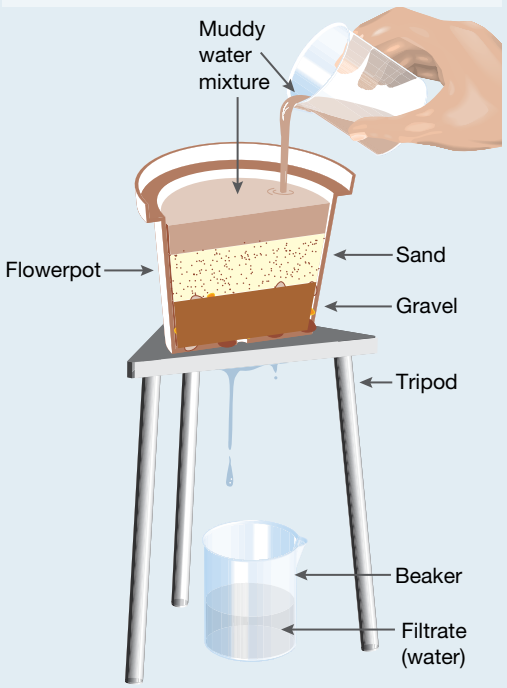
AIM: To produce clean water

You will need:

muddy water (muddy water made with clay is best)
alum (aluminium sulfate)
limewater
bleach
flowerpot
tripod
sand
gravel
two 250 mL beakers
stirring rod

- Pour 150 mL muddy water into the beaker.
- Add half a teaspoon of alum and 10 drops of limewater.
- Stir the water to mix the chemicals and allow the floc to form.
- Once you can see the floc forming, allow the water to stand and the floc to settle to the bottom.
- Add gravel and sand to the flowerpot to make the water filter as shown in the diagram at right.
- Decant the water from the beaker into your water filter. Collect the filtrate in a clean beaker.
- Add two drops of bleach (which contains chlorine) to your filtrate.

A flowerpot water filter



Discussion

1. Use a table like the one below to describe your water at each stage of the process. Include the appearance and odour of the water.

Treating dirty water

Treatment stage	Description of water
Untreated water	
Water after flocculation	
Water after filtering	
Water after chlorination	

2. Which separation techniques did you use to purify the water?
3. Prepare a series of picture diagrams to explain the steps you have taken to purify the water.

5.9 Exercises: Understanding and inquiring

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 chemicals that are added to Sydney's water and **explain** why they are added.
2. **Explain** why chlorine is added to water.
3. **Recall** five substances that can contaminate drinking water.
4. **Describe** the differences between blackwater and greywater.
5. **Describe** two ways in which greywater can be used on gardens without damaging plants.
6. **Explain** why alum is added to country water supplies.

Think

7. If you live in a country town that does not fluoridate the water, **describe** how you could obtain your fluoride.
8. **Describe** a natural method of separating mixtures that takes place in reservoirs over a long period of time.
9. At Taronga Zoo in Sydney, the water in the seal pool is chlorinated to a maximum of 1 part per million, which is less than the amount in swimming pools. **Explain** why such a small amount of chlorine is added to the water.
10. At the Melbourne Zoo seal pool, the water passes through a sand and gravel filter and polyaluminium chloride is added to the water. This chemical acts as a flocculant.
    (a) **Define** the term 'flocculation'.
    (b) What do you think the flocculant polyaluminium chloride does to the water entering the filter?

Investigate

11. Waste water in Taronga Zoo is generated by:
    - hosing down animal exhibits
    - filling animal and ornamental moats
    - flushing toilets
    - irrigating lawns.

    In 1998, it became the first zoo in the world to recycle its own waste water. **Investigate** the methods it uses to recycle the water.

12. The seal pool at Taronga Zoo and many swimming pools are vacuumed using a pool vacuum cleaner. **Investigate** how this type of vacuum cleaner works.
13. The seal pool at Taronga Zoo is also contaminated by the seals' own waste (the seals' sewage). **Investigate** how the amount of seal waste going into the main seal pool is minimised.
14. **Compare** the different brands of water filters available. Report on their cost, efficiency and ease of use. **Explain** why people consider the use of these filters to be necessary.

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Complete this digital doc: Worksheet 5.6: Water treatment (doc-12383)

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5.10 Project: The diamond flush

Scenario



Having only just been toilet trained, your little brother seems fixated on dropping stuff into the toilet and flushing it away. He has flushed away all sorts of things — Lego blocks, shopping lists, dog biscuits and even the occasional goldfish get put down the U-bend. It all seemed very funny until one day when he flushed away some really valuable things including a diamond ring, a pair of tiny diamond stud earrings, a wallet and a cultured pearl necklace. Your mum is absolutely frantic; but maybe, if you can track down where in the sewerage system they went, you have a chance of getting some things back for her!

Your task

Choose one of these valuable items and determine the most likely place that the missing object will be found. To do this, you will need to research the pathway taken by the sewage after it leaves your house and the different processes that the sewage (and the object) will be subjected to as it undergoes treatment. You will then put together a PowerPoint presentation that explains the pathway along which the object will have travelled once it left the house, the sewage treatment separation systems it would have passed through and where in the treatment system it is most likely to be found.

SUGGESTED SOFTWARE

- ProjectsPLUS
- Microsoft PowerPoint
- Word Draw, Paint or other drawing software
- Word processing software

5.11 Review

5.11.1 Study checklist

Mixtures

- **distinguish** between pure substances and mixtures and give examples of each **5.2**
- **recall** that a mixture can be separated according to specific properties of its components **5.2, 5.5, 5.7**
- **identify** some common mixtures **5.2, 5.3, 5.7**

Solutions

- **identify** the solute and solvent in common solutions **5.3**
- **describe** the difference between dilute, concentrated and saturated solutions **5.3**
- appreciate that water is a common solvent in solutions **5.3, 5.4, 5.7**
- **distinguish** between solutions and suspensions **5.4**
- **define** the terms 'colloid' and 'emulsion' **5.4**

Separating suspensions

- **describe** the processes of filtering, sieving, decanting and centrifuging **5.5**
- **compare** the effectiveness and limitations of these processes **5.5**
- **describe** common household uses of these separation techniques **5.5**
- **recall** how filtering and centrifuging are used in the isolation of blood products **5.6**

Separating solutions

- **describe** the processes of distillation, evaporation, crystallisation and chromatography **5.7**
- **explain** how distillation and evaporation may be used to purify water **5.7**

Applications and uses of science

- **describe** the processes used to separate materials in recycling plants **5.2**
- **describe** the processes by which sewage is treated **5.8**
- **evaluate** the appropriateness of current sewage treatment systems **5.8**
- appreciate that water often needs treating before it is drinkable **5.7, 5.9**
- **recall** common contaminants found in water **5.9**
- **identify** chemicals that are often added to water supplies and their purpose **5.9**
- **describe** how blood is separated into its components **5.6**
- **recall** how desalination plants separate fresh water from sea water **5.7**
- **explain** the process of homogenisation **5.4**

Individual pathways

ACTIVITY 5.1
Investigating mixtures
doc-10545

ACTIVITY 5.2
Analysing mixtures
doc-10546

ACTIVITY 5.3
Investigating mixtures further
doc-10547

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FOCUS ACTIVITY

online only

Blue-green algae has grown in a lake. It forms a fine, green suspension in the water. The local council wants to make the water clear again so that fish and other living organisms can safely inhabit the lake. **Propose** a method that you would use to solve the local council's problem. Remember that your method should not harm the fish already in the lake.

Access more details about focus activities for this topic in the Resources tab (doc-10544).

5.11 Review 1: Looking back

assessON

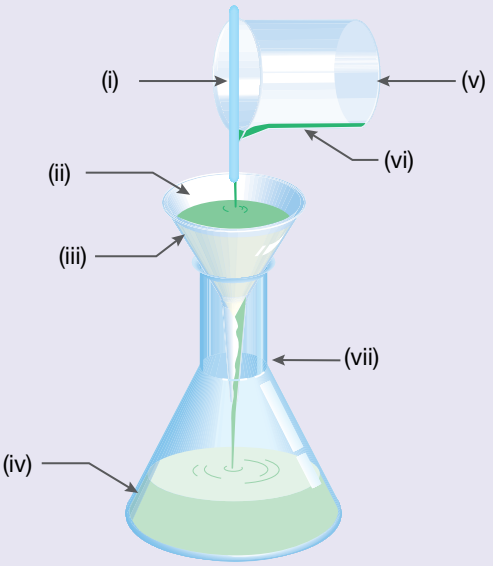
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

1. Copy and complete the table below to **summarise** what you know about separation techniques.

Method	How it works	An example of its use
Filtration		
Decanting		
Crystallisation		
Distillation		
Centrifuging		
Separating funnel		
Chromatography		

2. You have been asked to analyse some salt-contaminated soil and to **propose** a method for separating the salt from the soil.
   (a) Write out the method that you would use to obtain pure dry salt and pure dry soil.
   (b) Draw a labelled diagram showing how your equipment would be set up for each stage of your separation.
3. During an experiment, a teacher accidentally dropped some steel drawing pins into a bowl of sugar. **Propose** two methods that could be used to remove the drawing pins from the sugar. Briefly **explain** each method.
4. Black instant coffee is a mixture of coffee powder and hot water. **Identify** which substance is the:
   (a) solute
   (b) solvent
   (c) solution.

5. Pasta is cooked by boiling it in water. It sinks to the bottom of the saucepan when it is left to stand.
   (a) **Identify** what type of mixture the pasta and water is.
   (b) **Describe** two different methods that could be used to separate the pasta.
   (c) Which of the two techniques is best for separating the pasta and water? **Explain** your answer.
6. The diagram below shows a mixture being filtered in a school laboratory.
   (a) **Identify** each of the items or substances labelled (i) to (vii).
   (b) **Explain** the purpose of the stirring rod.



7. **Describe** what properties allow the following substances to be separated from a mixture.
   (a) Peas from a mixture of peas and water
   (b) Oil from a mixture of oil and water
   (c) Gold particles from a mixture of sand and creek water
   (d) Cream from cow's milk
8. **Recall** one good reason why each of the following objects or substances should not be tipped down the sink or flushed in a toilet.
   (a) Fat and oil
   (b) Cotton buds
   (c) Oven cleaner
9. **Assess** whether each of the following statements is true. If the statement is false, replace the word in *italics* with the correct word.
   (a) *Chromatography* can be used to separate substances with different solubilities.
   (b) The *heavier* parts of a mixture are forced to the outer edge of a centrifuge when it spins.
   (c) Suspensions contain *soluble* particles in a liquid.
   (d) A suspension can be separated in a *centrifuge*.
   (e) Milk is a *solution*.
   (f) Emulsions are a type of *colloid*.
10. **Explain** why blood collected from the Red Cross Blood Service needs to be separated before it is used.
11. **Describe** the purpose of an S-bend in a kitchen sink pipe.
12. **Identify** which of the following separation techniques are used in a water treatment plant. You may select more than one answer.
    (A) Filtration
    (B) Chromatography
    (C) Centrifuging
    (D) Sedimentation
    (E) Crystallisation
13. Oil floats on water. When detergent is added, the oil forms droplets in the water that do not settle. What type of mixture has been formed? **Justify** your answer.

Test yourself

1. **Identify** which of the following substances is a mixture.
   (A) Gold
   (B) Distilled water
   (C) Air
   (D) Carbon dioxide gas **(1 mark)**
2. **Identify** what would be the best method to use to separate iron filings from a mixture of sand, iron filings and salt.
   (A) Filtering
   (B) Magnetic separation
   (C) Sieving
   (D) Adding water to the mixture and then filtering **(1 mark)**
3. A sample of muddy river water can be described as
   (A) an emulsion.
   (B) a solution.
   (C) a colloid.
   (D) a suspension. **(1 mark)**
4. Centrifuging works best to separate substances with particles that have different
   (A) solubilities.
   (B) masses.
   (C) colours.
   (D) temperatures. **(1 mark)**
5. Read the story at the top of the next page and use the information to answer the questions below.
   (a) Write down what you think Marco would have said to his son. **Explain** the two methods clearly. **(3 marks)**
   (b) **Propose** three questions that Flavius would have asked in return. **(3 marks)**
   (c) *Extension*. **Construct** a flow chart that shows the steps involved in each salt harvest process using appropriate scientific terminology to **describe** changes of state and separation techniques.
   Spend some time researching ancient methods of salt separation before creating your flow chart. If using the internet, use search words such as 'ancient salt production', 'Roman times salt' or 'salt evaporation'.

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Complete this digital doc: Worksheet 5.7: Separating mixtures puzzle (doc-12384)

Complete this digital doc: Worksheet 5.8: Separating mixtures summary (doc-12385)

An ocean of salt

Salt has been used by civilisations for centuries to preserve meats, cure hides, make cheese and other foods and as flavouring in cooking. Salt was essential for life. Some communities even used salt instead of money as a form of payment. A community grew wealthy from its ability to produce salt.

Salt was mined from the ground, in the form of rock salt, or collected from sea water. The sea water, sometimes called brine, was evaporated and the salt collected. The brine was either heated over a wood fire or collected in shallow pools and left to heat in the sun.

'There's a whole ocean out there — full of salt — we just need to get it out of the water!', Marco remembered his grandfather saying. Marco lived during ancient Roman times. He lived in a town off the coast of the Mediterranean Sea. Marco himself now worked in the business his grandfather had started. He, too, marvelled at how he used the sun and winds to separate salt from sea water.





This day was special; it marked the day his son, Flavius, would first work at the salt business. As they reached the hill, they smelled smoke from the wood fires and looked out over the flat natural basin where salty water collected in shallow pools. Flavius saw that the smoke was from fires burning under large rectangular lead pans. Marco turned to his son and explained the two ways they separated salt from sea water.

TOPIC 6
The solar system

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.

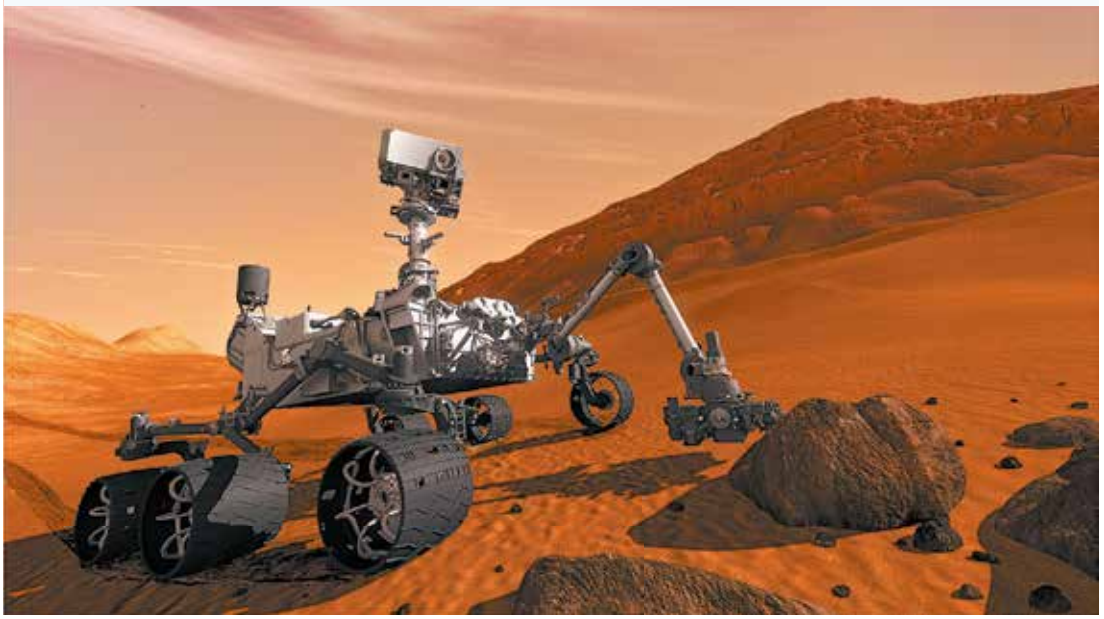
6.1.1 Why learn this?

Our understanding of the solar system continues to deepen with each new discovery. In the quest to determine whether Mars could ever have supported life, NASA successfully landed the rover named *Curiosity* on the surface of Mars in 2012. The rover has since discovered what appears to be an ancient stream bed, suggesting that water once flowed in large volumes across the Martian surface. This topic will take you on a journey through the solar system and explain important phenomena such as the seasons and the day/night cycle.

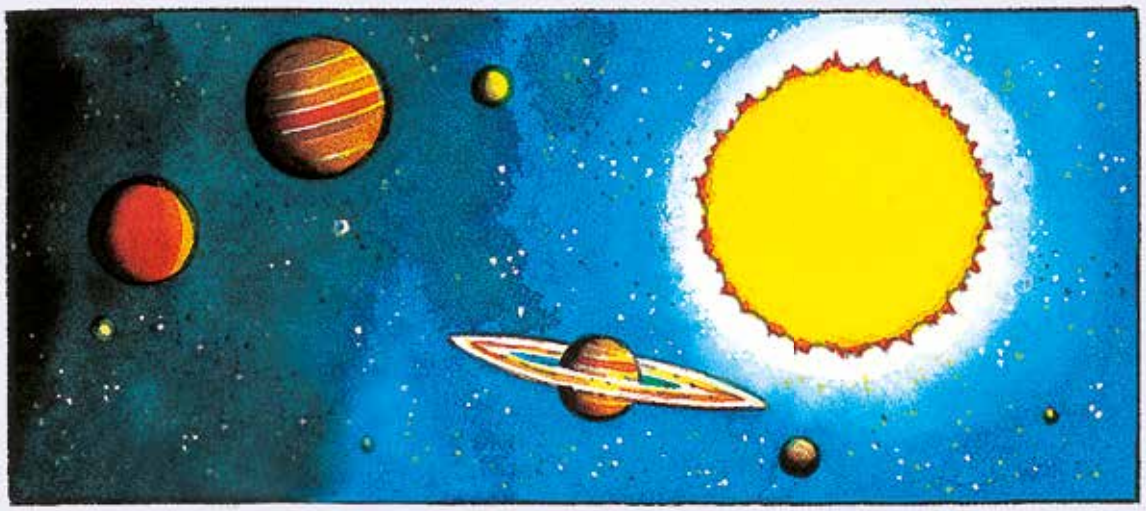
LEARNING SEQUENCE

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An artist's depiction of the *Curiosity* rover on the surface of Mars



What do you already know about the solar system?



1. Before you start working on this topic, draw a diagram on A3 paper of the sun and planets of the solar system. Draw the planets in order from the sun. Label each planet with its name.
2. Write down your answers to each of the following questions. There is no need to use any books or the internet to help. Your answers should be based on what you already know.
   (a) Which is the largest planet?
   (b) Which is the smallest planet?
   (c) Which two planets are closest to Earth?
   (d) Which planets have moons?
   (e) Which planets have rings?
   (f) Which planet has a surface that is frozen solid?
   (g) What else is there in the solar system apart from planets and moons?
3. The photos below were taken early in the morning at low tide and in the afternoon at high tide. Between the two tides, the water level rose vertically by 2–6 metres, but stretched much further horizontally along the beach. What causes such changes?
4. Discuss the following questions with others in your class and write down answers to each after your discussion.
   (a) What do you think a 'shooting star' is?
   (b) Can we see any planets from Earth? If so, which ones?
   (c) Why can you see more stars at night when you are out in the countryside than when you are in the city?
   (d) If our Earth is shaped like a sphere, why don't we fall off?
   (e) How is the moon different from Earth?
5. A friendly alien has landed near your house. He asks you the two questions below to try to understand our part of the universe. How would you answer him? Draw diagrams that help explain your answers.
   (a) Why can you Earth people see the moon but not the sun at night?
   (b) What makes your moon shine?





6.2 Voyage to the planets

Science as a human endeavour

6.2.1 The solar system

The solar system consists of eight planets travelling around a central star that we know as the sun. These planets travel around the sun in an almost circular path called an **orbit**. The orbits are actually in the shape of an ellipse, which is slightly oval in shape. The orbits of some planets are more circular than others.

Until 2006, our solar system was considered to contain nine planets. The four inner planets — Mercury, Venus, Earth and Mars — are classified as **terrestrial planets** (terrestrial means 'like Earth'). They are small and solid. The next four — Jupiter, Saturn, Uranus and Neptune — are classified as **gas giants**. These huge planets do not have a solid surface.

Pluto was considered the ninth and outermost planet. However, in 2003, the discovery of an orbiting rocky object, named Eris, which is similar in size to Pluto but further away from the sun, created debate about what defines a planet. In 2006, astronomers agreed that, to be called a planet, a celestial body must:

- be in orbit around a star, while not itself being a star
- be large enough in mass for its own gravity to cause it to be nearly spherical in shape
- travel in an orbit that does not overlap with other objects, including planets.

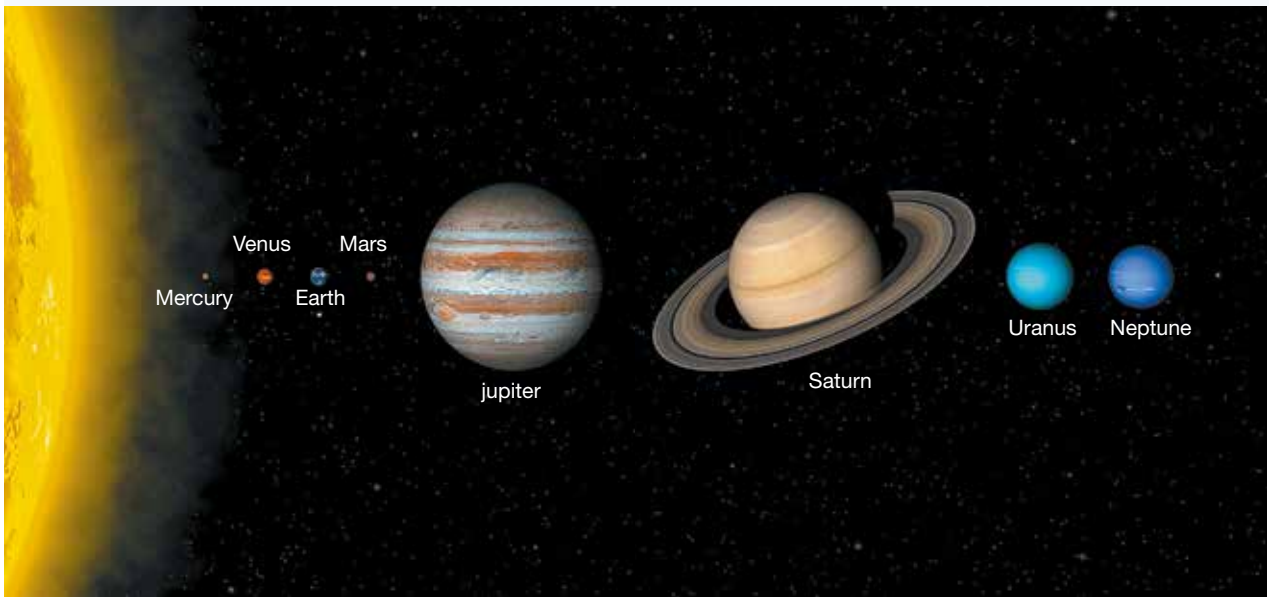
As a result, Pluto and Eris were disqualified as major planets and instead were classified as dwarf planets. In the case of Pluto, the main reason for this was that its orbit overlaps Neptune's.

The planets Mercury, Venus, Mars, Jupiter and Saturn can all be seen without using a telescope. All of these planets were discovered in ancient times. They were noticed among the many stars in the sky because they move in regular patterns against the background of stars. In fact, the word 'planet' comes from a Greek word meaning 'wanderer'.

The most distant planets, however, cannot be seen without telescopes and were discovered more recently. Uranus was discovered by accident with a telescope in 1791. Neptune was discovered in 1846 and the dwarf planet Pluto in 1930.

All of the planets spin, or **rotate**, as they orbit the sun. The Earth rotates once every 24 hours. This period is called one day. Jupiter takes only about 10 hours to rotate. That means that a day on Jupiter is only 10 hours long. Venus takes 243 Earth days to complete one full rotation.

The planets of the solar system with their sizes drawn to scale (but not their distances from the sun)



Key features of the planets of the solar system

Planet	Period of orbit (compared with Earth)	Period of rotation (compared with Earth)	Gravitational force (compared with Earth)	Average surface temperature (°C)	Number of satellites
Terrestrial planets					
Mercury	88 days	59 days	0.38	–180 to 420	0
Venus	225 days	243 days	0.91	450	0
Earth	1 year	1 day	1.00	22	1
Mars	687 days	24.5 hours	0.38	–120 to –30	2
Gas giants					
Jupiter	12 years	10 hours	2.9	–140	At least 62
Saturn	29 years	11 hours	1.3	–170	At least 33
Uranus	84 years	17 hours	0.93	–210	At least 27
Neptune	165 years	16 hours	1.2	–220	At least 13

INVESTIGATION 6.1

The scale of the solar system

AIM: To develop an understanding of the scale of the solar system

You will need:

cardboard
marking pens
trundle wheel
basketball
2 golf balls (or table tennis balls)
2 marbles
2 peas
2 silver cachous (small shiny spheres used to decorate cakes)

- Make nine large cardboard labels for your class: one for the sun and one for each planet.
- Collect a basketball to represent the sun, and each of the items listed in the table below to represent the planets, and move to a large outdoor area.
- One student should be selected to hold the 'sun' and its label. Eight teams of students should also be selected to carry the 'planets' and their labels to the correct distances from the 'sun'. If you don't have a trundle wheel, assume that each pace is 1 metre long.
  (The model created here is not quite to scale for both planet size and distance from the sun.)

A model of the solar system

Planet	Item representing planet	Distance from the 'sun' (metres)
Mercury	Silver cachou	1.5
Venus	Pea	2.7
Earth	Pea	3.7
Mars	Silver cachou	5.7
Jupiter	Golf ball	20
Saturn	Golf ball	36
Uranus	Marble	72
Neptune	Marble	110

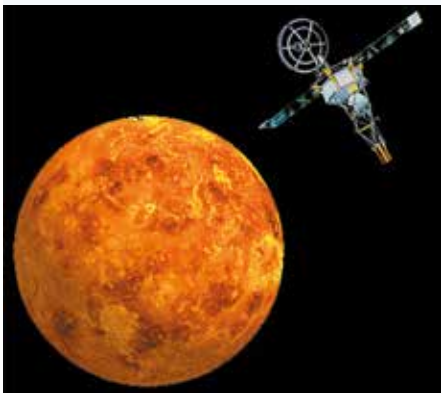
Discussion

1. Describe your model in words. Does it surprise you in any way?
2. Outline why this modelling exercise is useful in understanding the solar system.

6.2.2 Space probes providing new insights into the solar system

Our understanding of the solar system has increased substantially through the use of technology. Galileo first described the craters on the moon in 1610 using an early telescope. Today, astronomers have a sophisticated array of ground-based and satellite-based telescopes to collect data from the far reaches of the solar system. From the 1960s, NASA (the American National Aeronautics and Space Administration) began to develop probes that could be launched into space to collect data from the planets in our solar system from closer proximity.

An artist's depiction of *Mariner 2* approaching Venus



Venus is the closest planet to the Earth and the brightest object in the night sky apart from the moon. However, thick clouds above the planet made the surface of Venus a mystery until the *Mariner 2* mission. This space probe became the first successful mission to another planet when it flew past Venus in 1962. *Mariner 2* scanned the planet with infra-red and microwave sensors, revealing that Venus has an atmosphere containing mainly carbon dioxide and an extremely hot surface, over 425 °C. The probe also confirmed that Venus rotates in the opposite direction to most of the other planets in our solar system and, unlike the Earth, Venus has no detectable magnetic field. *Mariner 2* was also the first spacecraft to sample the solar wind, a constant stream of charged particles flying outward from the sun.

Mercury is the closest planet to the sun and quite small compared with Earth. The surface of Mercury is very much like that of the moon. It is very heavily cratered and has mountains, valleys and flat plains just like the 'seas' on the moon. Until 1974, prior to the *Mariner 10* mission to Mercury, the planet was believed to have no atmosphere. The gravitational pull on Mercury is much smaller than that on Earth so that gases tend to escape into space. However, *Mariner 10* detected a thin atmosphere with traces of the gases helium and hydrogen and even smaller amounts of several other gases.

6.2.3 Mission to Mars

Mars is about half the diameter of Earth and, after Earth, its orbit is next furthest from the sun. Mars' red appearance is due to dust blown over its surface by light winds. Like Mercury, it has little gravitational pull and a thin atmosphere without clouds, making it possible to observe its surface from Earth using telescopes. In fact, in 1877, one astronomer observed what appeared to be canals on the surface. This observation led to the widely held belief that there was life on Mars. The *Mariner 4* mission was launched in 1964 and, after an eight-month voyage to the red planet, the spacecraft flew past Mars collecting the first close-up photographs of another planet. The pictures, played back from a small video recorder, showed lunar type impact craters.

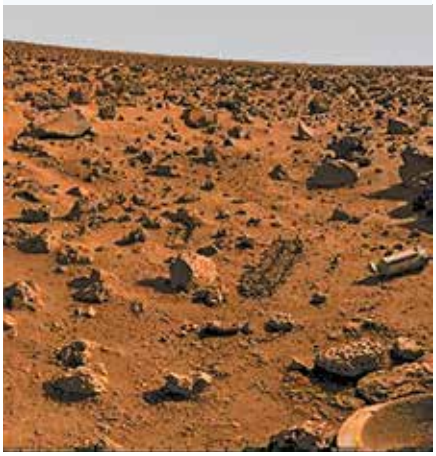
The *Viking* lander, the first spacecraft to land successfully on another planet



In the years that followed, NASA set about to develop a spacecraft that could land on the surface of Mars to collect and analyse samples in search of any signs of life, either past or present. In 1975, the *Viking 1* and *2* probes were launched. Each consisted of an orbiter and a lander designed to take high-resolution images to study the Martian surface and atmosphere. The orbiter snapped images on approach that helped mission controllers navigate the landers to safe landing sites. These images revealed icecaps at the poles and large volcanoes. The icecaps were believed to be made of frozen carbon dioxide (dry ice) and frozen water. The largest volcano, Olympus Mons, towers 25 kilometres above the surface, with a diameter of 600 kilometres and well over twice the height of Mount Everest. The pictures showed a dry, barren surface with no evidence of any form of life. However, there

are what appear to be dried-up river beds. It was believed that these river beds were formed by water millions of years ago and that there may still be frozen water beneath the surface.

Image of the surface of Mars taken by the *Viking* lander



The landers were successfully deployed, and analysis of the soil samples provided no clear evidence of the presence of living micro-organisms in soil near the landing sites. The mission biologists believe that the combination of intense ultraviolet radiation from the sun and extreme dryness of the soil prevent the formation of living organisms in the Martian soil. However, the question of whether life may have existed on Mars in the past remains open. While the landers' chemical-sensoring instruments found no sign of organic molecules (the building blocks of cells) they did find all the elements essential to life: carbon, nitrogen, hydrogen, oxygen and phosphorus. In addition, water vapour was found to be relatively abundant in the far north during the summer, with the north pole covered permanently in ice.

The next technological development in the exploration of the planets was the construction of mobile landers, or rovers, capable of surveying a planet, and collecting and analysing samples from the planet surface as directed by mission controllers. The Mars *Pathfinder* mission, launched in 1996, was the first wheeled vehicle to be used on another planet in the solar system and served as the foundation for the latest Mars rovers. More recently, the *Curiosity* rover, the most technologically advanced rover ever built, landed in Mars' Gale Crater in 2012 using a series of complicated landing manoeuvres never before attempted. The specialised landing sequence used a giant parachute, a jet-controlled descent vehicle and a bungee-like

NASA's Mars *Curiosity* rover, a mobile robot for investigating Mars' past or present ability to sustain microbial life. The rover examines a rock on Mars with a set of tools at the end of its arm, which extends about 2 metres. Two instruments on the arm can study rocks up close. Also, a drill can collect sample material from inside rocks and a scoop can pick up samples of soil. The arm can sieve the samples and deliver fine powder to instruments inside the rover for thorough analysis. The mast, or rover's 'head', rises to a height of 2.1 metres and supports two remote-sensing instruments: the mast camera, or 'eyes', for stereo colour viewing of surrounding terrain and material collected by the arm; and the ChemCam instrument, which is a laser that can vaporise material from rocks up to about 9 metres away and determine the chemical composition of the rocks.

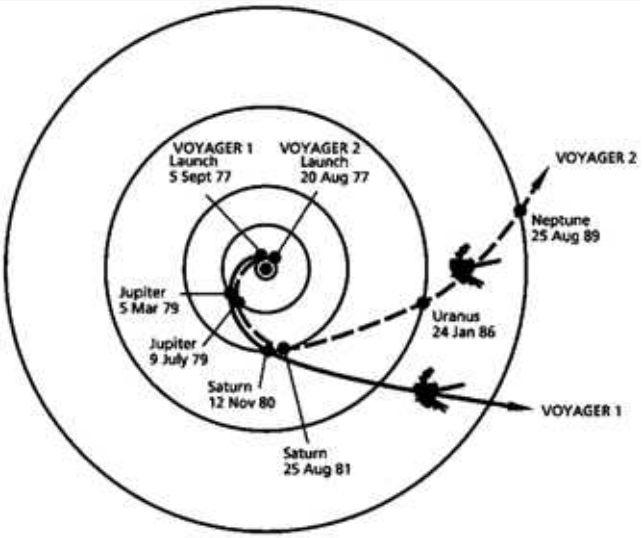


apparatus because landing techniques used during previous rover missions could not safely accommodate the much larger and heavier rover with its payload of scientific equipment. *Curiosity*'s mission is to determine whether the red planet was ever habitable by microbial life. The rover, which is about the size of a small car, is equipped with 17 cameras and a robotic arm containing a suite of specialised laboratory-like tools and instruments, including a laser able to drill holes in rock samples to allow the rock composition to be tested.

6.2.4 Voyage to the gas giants

The four largest planets, Jupiter, Saturn, Uranus and Neptune, lie well beyond the planet Mars. These planets are called the gas giants because they are like huge balls of gas. They do not have a solid surface like the terrestrial planets Mercury, Venus, Earth and Mars. The gas giants gradually change their physical state from gases in their deep atmospheres to liquids and solids closer to the centre. They are composed mainly of hydrogen, helium and methane. The *Voyager 2* spacecraft, in operation since its launch in 1977, has visited all the gas giants, with a flyby of Jupiter in 1979, Saturn in 1980, Uranus in 1986 and Neptune in 1989. Throughout its journey *Voyager 2* sent back pictures showing that all of the gas giants had ring systems around them. Prior to this mission, it was believed that Saturn was the only planet with rings. In addition it has discovered and photographed many of the gas giants' moons. It is the most distant human-made object ever to have travelled from the Earth. In 1998, engineers switched off the spacecraft's non-essential instruments to conserve power. Data from at least some of the six instruments still in operation should be received until at least 2025, by which time *Voyager 2* is destined to be well beyond the boundaries of the solar system.

Voyager 2 and its partner *Voyager 1* are the first spacecraft to have travelled beyond the solar system.



Voyager 2 aboard the *Titan III–Centaur* launch vehicle lifted off on 20 August 1977.



6.2.5 Jupiter

Jupiter, the largest of all the planets, can be seen from Earth without a telescope, and its largest four moons can be seen with a small pair of binoculars. It has a giant hurricane, called the Great Red Spot, which is over twice the size of the Earth. This hurricane was first observed over 300 years ago! Jupiter rotates so quickly that it bulges at its equator. A thin ring of fine dust was detected around Jupiter by both of the *Voyager* space probes in 1979. In a more recent NASA mission, the space probe *Galileo* was sent towards Jupiter, arriving in 1995. It provided detailed information on the moons of Jupiter, including discovering

evidence of salt water below the surface of the moons Europa, Ganymede and Callisto and new insights into the intensity of volcanic activity on the moon Io.

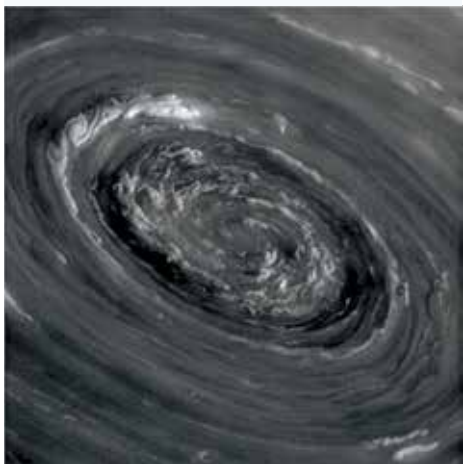
Space probe *Galileo* made numerous discoveries about Jupiter and its moons.



6.2.6 Saturn

Saturn has a system of rings around its equator that is several kilometres thick. The rings are difficult to see when their edge faces the Earth. There are seven rings consisting of thousands of smaller ringlets. The ringlets appear to be made up of small particles of ice-coated rock revolving around the planet like tiny moons. Like Jupiter, it bulges at its equator because of its rapid rotation. The *Cassini* mission to Saturn, launched in 1989, is a joint endeavour of NASA and the European Space Agency (ESA). The *Cassini* spacecraft landed a probe on Titan, Saturn's largest moon, in 2005. Scientists were keen to investigate Titan as its atmosphere, like that of Earth, contains both nitrogen and oxygen, but the oxygen is likely to be in the form of ice water. Interestingly, Titan's atmosphere also contains a mixture of complex organic molecules. It is thought that, if Titan received more sunlight, its atmosphere might more closely resemble that of a primitive Earth. Most scientists agree that conditions on Titan are too cold for life to have evolved. Even if Titan proves to be lifeless, understanding the chemistry on this distant moon may help us better understand the chemical origins of life on Earth.

Image of a swirling vortex above the north pole of Saturn taken by NASA's *Cassini* spacecraft in 2012. The vortex is swirling at 480 km/h with a diameter greater than that of the Earth. *Cassini* will continue orbiting the planet until 2017.



6.2.7 Uranus

Uranus appears blue from the Earth due to methane gas in its atmosphere. The axis of rotation of Uranus is almost in line with the sun. This means that light from the sun falls on one pole for a very long time. Like Jupiter and Saturn, Uranus bulges at the equator because of its rapid rotation. This rapid rotation also creates very strong winds in its atmosphere. Uranus has a system of about 11 rings that are smaller and fainter than those of Saturn.

NASA's *Cassini* orbiter captured this view of Saturn in 2009. A narrow shadow is cast on the surface of the planet by the rings.



6.2.8 Neptune

Neptune, like Uranus, appears blue from the Earth due to methane gas in its atmosphere. It has a system of five faint rings that appear to consist of dust particles. It has a large dark spot similar to Jupiter's Great Red Spot. This dark blue spot, which is larger than Earth, is believed to be a giant storm. It was discovered in 1989 by the space probe *Voyager 2*, which also discovered six of the planet's moons. One of Neptune's moons, Triton, is the coldest known body in the solar system.

INVESTIGATION 6.2

What keeps the planets in the solar system?

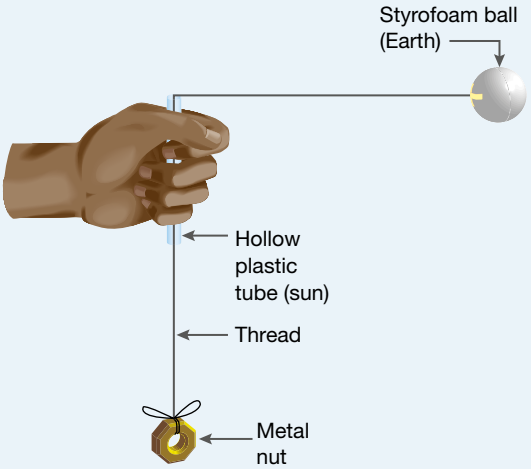
AIM: To model the gravitational force of the sun

You will need:

styrofoam ball
one metre of thread
sticky tape
small metal nut or similar weight
hollow plastic tube or empty biro case
scissors

- Tape a piece of thread to a styrofoam ball or table tennis ball and pass it through a hollow plastic tube. Tie the other end to a large metal nut or similar weight. The ball represents a planet and the plastic tube represents the sun.
- Move to an area in the playground where you are several metres away from all other students. Hold the plastic tube in your hand and whirl the ball in a circle as shown in the diagram at right.
- Cut the thread just below the plastic tube while the ball is being whirled and observe the motion of the ball.

There must be a force to keep the ball moving in a circle. What force keeps the planets in orbit around the sun?



Discussion

1. What force prevents the ball in this activity from flying off into the distance while it is in orbit?
2. The planets are obviously not tied to the sun with a string. What is the name of the force that keeps the planets from escaping from the sun and the solar system?
3. Describe what happened to the ball when the thread was cut.
4. What would happen to the planets if the sun suddenly disappeared from the solar system?

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. **Construct** a mnemonic to remember the eight planets in order from the sun.
2. **Identify** the
   (a) terrestrial planets (b) gas giants.
3. **Propose** why Uranus, Neptune and the dwarf planet Pluto were discovered much later than the other planets.
4. **Identify** the space mission(s) that
   (a) detected the thin atmosphere of Mars
   (b) travelled on the surface of Mars, collecting data
   (c) investigated Io, a moon of Jupiter
   (d) has travelled beyond our solar system.

Think

5. The table at the top of next page shows how the size and distance from the sun of other planets compare with the dimensions for Earth.

How the other planets compare with Earth

Planet	Diameter at equator (Earth = 1 unit)	Average distance from the sun (Earth = 1 unit)
Mercury	0.38	0.39
Venus	0.95	0.72
Earth	1.00	1.00
Mars	0.53	1.52
Jupiter	11.2	5.19
Saturn	9.41	9.43
Uranus	3.98	19.1
Neptune	3.81	29.9

Follow the instructions below to **construct** two scale drawings of the solar system. The first drawing will show how the sizes of the planets compare with each other. The second drawing will show how far the planets are from the sun.

(a) On a sheet of A3 paper, draw a circle to represent the size of each of the planets in the order listed above. Use the diameter in Earth units from the table above and a scale of 1 cm = 1 Earth unit. Colour and label each planet.

(b) Turn the sheet over and rule a 40 cm line across the centre. At one end of the line, draw a large dot and label it as the sun. Use the distances in Earth units from the table to draw a dot representing each planet on your line. Again, use a scale of 1 cm = 1 Earth unit. Label each planet.

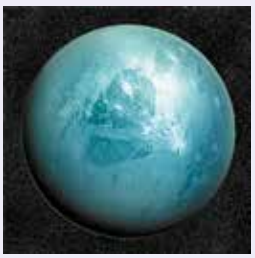
6. **Explain** why scientists have thought it possible for life to exist on Mars.
7. **Explain** why our knowledge of the gas giants increased so dramatically between 1979 and 1989.

Create

8. Draw a column graph to **compare** the time taken for an orbit by each of the four gas giants. **Identify** whether there is a trend in the orbital time for these planets.
9. Create a PowerPoint or Flash presentation or a tourist brochure to entice people to visit the planet Mars. You should include information about
   (a) the trip to and from Mars
   (b) accommodation on Mars
   (c) weather conditions and atmosphere
   (d) the surface, including sights to see
   (e) how to get around while on the planet
   (f) leisure activities, especially those that would be different from those on Earth
   (g) excursions to the two moons.
10. **Create** a timeline, drawn to scale, to sequence the NASA missions within the solar system.

Investigate

11. Until 2006, Pluto was considered the ninth planet of the solar system. Find out
    (a) when it was discovered and by whom
    (b) how Pluto differs from the eight planets
    (c) whether it has any moons and, if so, their names
    (d) how long Pluto's orbit of the sun takes.
12. The decision by astronomers not to consider Pluto (shown at right) as a planet in our solar system was momentous and somewhat controversial. Take the role of a journalist and write a newspaper article announcing the decision to strike Pluto off the list of planets. Include an outline of the conflicting views of scientists on this issue.



Evaluate

13. Write a 400-word essay with examples to explain how advances in technology have enhanced our understanding of the solar system.

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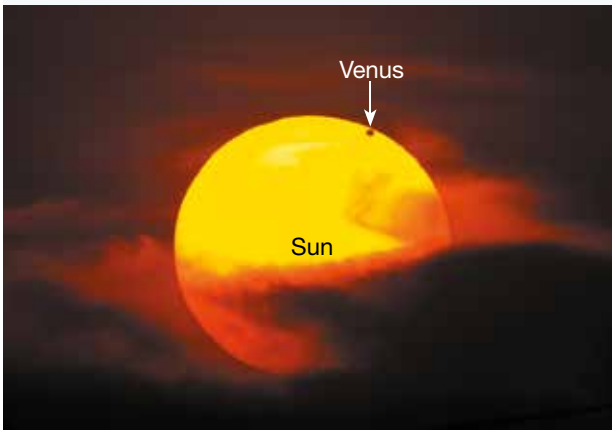
Complete this digital doc: Worksheet 6.1: The solar system (doc-12386)

6.3 A very important star

6.3.1 The sun

The sun is a star at the centre of the solar system and over a million times larger than the Earth. The sun accounts for 99.8 per cent of the mass of our solar system. The majority of the remaining 0.2 per cent is accounted for by Jupiter. The sun is one of billions of stars in the **universe**. Our next closest star, Proxima Centauri, is very far away, more than four light-years away in fact. This means that a beam of light from Proxima Centauri travelling 300 000 km/s takes over four years to reach Earth; light travelling from the sun takes approximately 8 minutes to reach the Earth.

A time-lapse photograph of the transit of Venus in 2012 illustrating the immense size of the sun compared with the planets. The next transit will not occur until 2117!



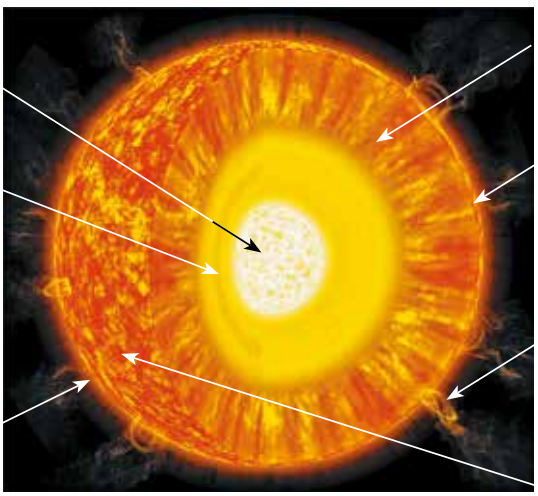
HOW ABOUT THAT!

Like all of the planets, the sun rotates around its own axis. It therefore has two poles and an equator. Because it is not solid, different parts of the sun rotate at different speeds. At its equator, the sun rotates once every 25 days. At the poles, it takes 34 days for a full rotation.

6.3.2 Generating heat and light

Planets and moons are visible in the night sky because they reflect the light produced by the sun. Like other stars (but unlike planets and moons), the sun generates light and heat through a nuclear fusion reaction in its core. This fusion reaction requires the immense heat of its core, where the temperature is believed to be about 15 million °C; the temperature at the surface of the sun is about 6000 °C. In this reaction, hydrogen atoms are fused together producing helium atoms and a great deal of energy. This energy travels out from the core through several layers of the sun before it escaped into space as sunlight.

The sun has a complex internal structure. The fusion of hydrogen atoms in the core generates light and heat that travel through several layers of the sun before escaping from the surface.



INVESTIGATION 6.3

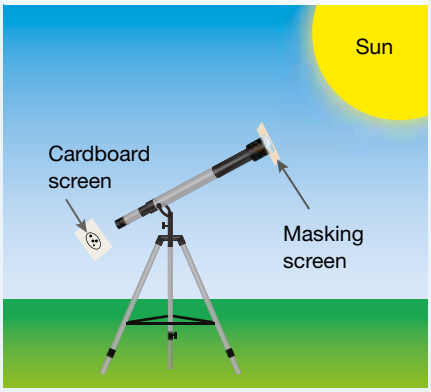
Observing sunspots

AIM: To observe sunspots

You will need:
cardboard
tripod-mounted telescope

SAFETY WARNING: The sun should never be observed directly, either with the naked eye or through a telescope or binoculars. Damage to the eyes can result from direct observation.

Projecting sunspots onto a screen



- Cut out a masking screen to fit over the front of the tube of the telescope.
- Position the tripod and telescope so that it is directed towards the sun, but do not look through the telescope to align it; rather, use the shadow cast on the ground as an indication of the correct position.
- Hold or position a sheet of cardboard 0.5–1.0 metre behind the eyepiece of the telescope to capture the image of the sun and to view any sunspots. You may need to adjust the eyepiece focus knob and the cardboard screen to obtain a sharp image.
- Record your observations in your notebook using a labelled illustration.

Discussion

1. How many sunspots did you observe? Were they positioned close together?
2. Are all the sunspots similar in size?

6.3.3 Sunspots

Sunspots are darker, cooler areas on the surface of the sun, which is called the photosphere. Sunspots can be very large, up to 50 000 kilometres in diameter. They are caused by interactions with the sun's magnetic field. Sunspots occur over regions of intense magnetic activity and, when that energy is released, solar flares and large eruptions, called coronal mass ejections, emerge from the sunspots. Sunspots typically last anywhere from a few days to a few months.

6.3.4 Solar radiation — essential for life

The sun provides the planets with heat, light and other forms of energy. The energy released from the sun is called *solar radiation*. Solar radiation reaches all of the planets.

All the different types of energy coming from the sun form the electromagnetic spectrum. This includes visible light, infra-red radiation, ultraviolet radiation and even X-rays and gamma rays.

Life exists on Earth because the atmosphere allows the right amounts of each type of solar radiation to reach the surface. Solar radiation provides:

- the light needed by plants so that they can grow and make their own food using a process called photosynthesis. Animals rely on plants as a source of food. Even animals that do not eat plants eat other animals that do eat plants.
- heat, which keeps the atmosphere, the Earth's surface and bodies of water warm enough to support life. The sun controls our climate. Heat is released from the sun in the form of **infra-red radiation**. Infra-red radiation is not visible to the human eye. Some gases in the Earth's atmosphere trap infra-red radiation from the sun. This makes the atmosphere heat up. This process is called the **greenhouse effect**. The atmosphere of Venus is mostly carbon dioxide, which absorbs a lot of infra-red radiation. The greenhouse effect is responsible for the extremely high temperatures on Venus.
- **ultraviolet radiation**, which is needed by humans to help the body make vitamin D. The amount required can be obtained by being outdoors in the open for just a few minutes each day. However, the ultraviolet radiation emitted from the sun is also the cause of sunburn and can lead to skin cancer.

INVESTIGATION 6.4

Sunspot activity

AIM: To investigate data on sunspot activity to see if there is a pattern

You will need:

graph paper

The following data were collected on the average number of sunspots recorded each year from 1970 to 2004.

- Plot the number of sunspots (vertical axis) against years (horizontal axis) on a sheet of graph paper.
- Join the data points with a ruler.

Discussion

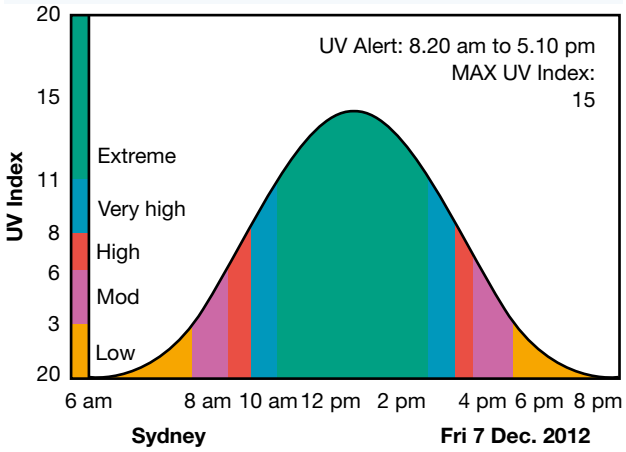
1. Is there a pattern in the data?
2. Approximately how long is there between periods of high sunspot activity and periods of low sunspot activity?
3. Predict whether there will be many or few sunspots
   (a) this year
   (b) the year you turn 18.

Year	Average number of sunspots	Year	Average number of sunspots
1970	109	1988	89
1971	74	1989	148
1972	72	1990	149
1973	39	1991	146
1974	34	1992	96
1975	15	1993	54
1976	14	1994	36
1977	30	1995	19
1978	103	1996	9
1979	156	1997	22
1980	141	1998	65
1981	141	1999	94
1982	116	2000	120
1983	72	2001	111
1984	44	2002	104
1985	17	2003	64
1986	12	2004	41
1987	28		

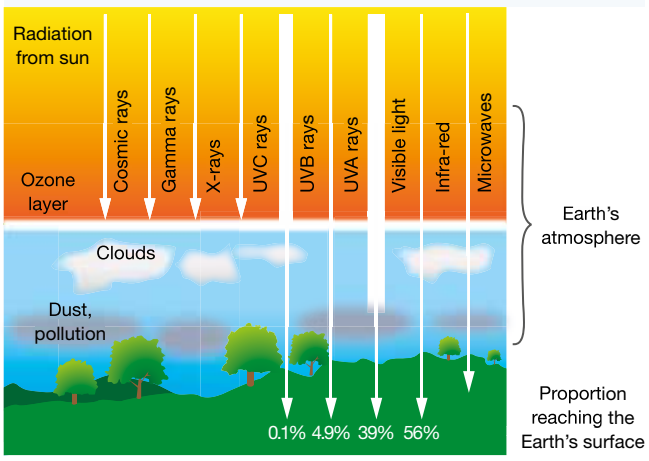
UV radiation is not related to temperature, so you can still get sunburned on cool, cloudy days. The Bureau of Meteorology provides a daily forecast of the sun's UV radiation intensity. This is called the UV index. It divides UV radiation levels into low (1–2), moderate (3–5), high (6–7), very high (8–10) and extreme (11 and above). In Australia, UV radiation levels are most intense from the beginning of September to the end of April, particularly between 11 am and 3 pm. When UV levels are 3 and above, sun protection is needed because the UV radiation is intense enough to damage the skin.

The ozone layer high in the Earth's atmosphere absorbs much of the ultraviolet radiation reaching the Earth from the sun. If humans were living and working in sunlight on the moon or Mars, they would need a lot more protection from ultraviolet radiation than on Earth. Like infra-red radiation, ultraviolet radiation is not visible to the human eye.

The daily forecast of the sun's UV intensity allows us to predict the time of day when the sun's rays will be most damaging to our skin.



The Earth's atmosphere filters some of the electromagnetic radiation from the sun.



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. **Outline** how the sun produces the huge amount of energy that it releases. Where does this process occur and why?
2. **Identify** the types of radiation emitted by the sun.
3. **Identify** one type of solar radiation that
   (a) is absorbed by the ozone layer
   (b) heats the Earth's surface.

Think

4. **Explain** why life on Earth would not be possible without the sun.
5. **Explain** why there is no greenhouse effect on Mars.
6. **Explain** why you would need protection from the sunlight on Mars, even though it is very cold.
7. All of the Earth's fossil fuels, including coal, petroleum and natural gas could be described as stored solar energy. **Explain** why. (*Hint:* Think about how they are formed.)

Investigate

8. Find out more about one of the following sun topics and present your findings.
   - Sunspots and how they can affect the Earth
   - What causes the northern lights (aurora borealis) and southern lights (aurora australis)
   - How the Earth is protected from the particles and radiation from the sun
   - Space probes sent to study the sun

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Complete this digital doc: Worksheet 6.2: The sun (doc-12387)

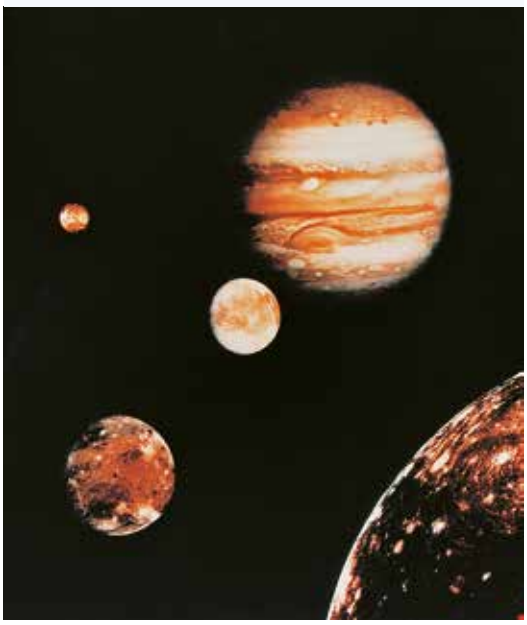
6.4 Rocks in space

6.4.1 Moons

The solar system contains many objects other than the sun and the planets. All of the planets except Mercury and Venus have moons. Each moon is held in orbit around its planet by a gravitational force.

The moons vary greatly in size. Deimos, the smaller of the two moons of Mars, is only about 10 kilometres in diameter. The largest known moon in the solar system is Ganymede, one of the 16 moons of Jupiter. It is larger than the planet Mercury. Some moons, like the Earth's moon, are cratered while others are quite smooth.

Jupiter and three of its moons



6.4.2 Asteroids

Thousands of small, irregular objects called **asteroids** orbit the sun just like the planets. Most of them are between the orbits of Mars and Jupiter — a region sometimes called the **asteroid belt**. The largest

asteroid, Ceres, is about 970 kilometres in diameter. The smallest known asteroids are only about one kilometre across.

The orbits of asteroids are more elliptical in shape than the orbits of the planets. This brings them quite close to the sun and to the orbit of Earth. In 1991, a small asteroid passed within 170 000 kilometres of Earth. That is less than half the distance from the Earth to the moon and dangerously close. It passed Earth at a speed of about 72 000 kilometres per hour.

In 1993, the space probe *Galileo*, on its way to Jupiter, discovered the first known moon of an asteroid. A body of rock about one kilometre across was photographed orbiting a potato-shaped asteroid called Ida. It is likely that many asteroids have moons.

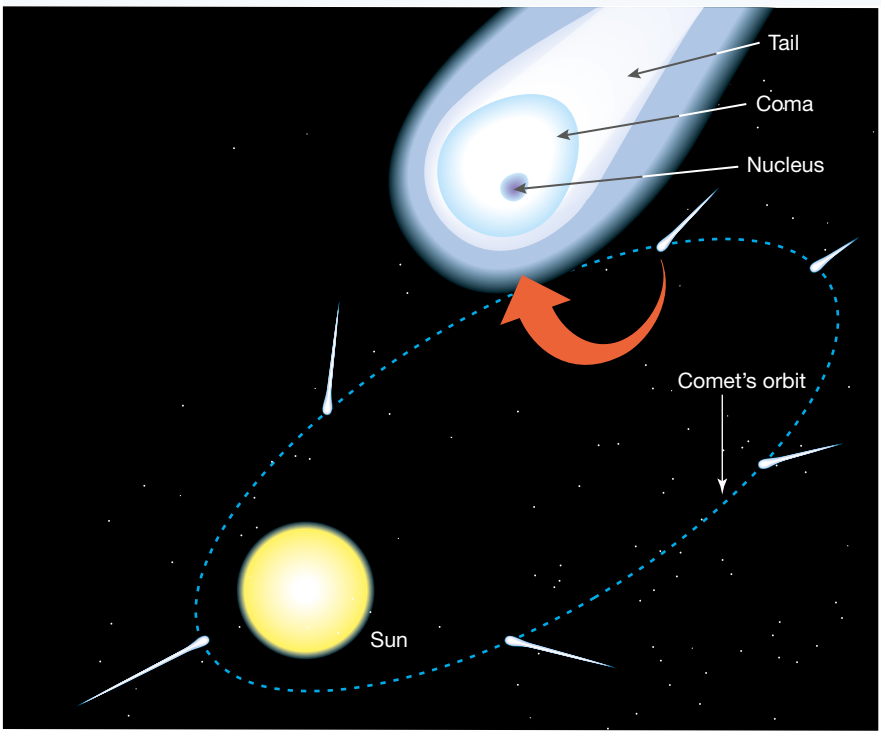
Most asteroids have irregular shapes.



6.4.3 Comets

Comets are balls of rocky and metallic particles amid ice and frozen gases. Most of the mass of a comet is in its nucleus. A bright glowing tail of dust and gases becomes larger as the comet moves closer to the sun. Up to millions of kilometres long, the tail is blown away from the sun by the solar wind.

The orbit of a comet is long and narrow. The tail gets longer as the comet approaches the sun.



It is believed that comets are formed from dust and ice in the cold, outer regions of the solar system.

The most famous comet is Halley's comet, named after Sir Edmond Halley, who correctly predicted that it would return every 76 years. Its orbit extends beyond the orbit of Neptune. We see it as it passes near Earth on its path to and from the sun. This last happened in 1986.

6.4.4 Meteoroids

Occasionally people see bright streaks of light called 'shooting stars' in the night sky. The streaks of light are called **meteors**. They are created when a lump of rock or metal burns up as it passes through the Earth's atmosphere. Lumps of rock or metal that travel around the solar system orbiting the sun are called **meteoroids**. Most of those that cross the path of the Earth's orbit are so small that they burn up completely before they reach the ground. Those that are large enough to reach the ground are called **meteorites**. Meteorites hit the ground with speeds of up to 70 kilometres per second, or 252 000 kilometres per hour. They are very hot and explode on impact, leaving craters much bigger than themselves. The Wolf Creek crater in Western Australia, pictured at right, has a diameter of about 850 metres. The crater's rim rises about 25 metres above the surrounding plains and its floor is about 50 metres below the rim.

Some scientists believe that a meteorite caused the extinction of the dinosaurs about 65 million years ago. They believe that the impact of the meteorite lifted tonnes of dust into the atmosphere, blocking out sunlight from the surface for several months. This would have killed all plants and changed the climate, making it impossible for larger animals like dinosaurs to survive.

The Wolf Creek meteorite crater in Western Australia



INVESTIGATION 6.5

Meteorite impact

AIM: To model the formation of craters

You will need:

large plastic tray or tub
damp sand
rocks ranging in size from 2 to 5 cm in diameter
metre ruler

- Design an investigation to model the effect of the size of a rock and the height from which a rock is dropped on the diameter and depth of the crater that is formed.
- Be sure to conduct a controlled experiment. If you are varying the size of the rock, keep the height from which it is dropped constant. Similarly, if increasing the height from which the rock is dropped, keep the size of the rock constant.
- Repeat each experiment twice and record an average diameter and depth in the damp sand.
- Draw a line graph to show the pattern between any two variables you investigated. For example, you might like to show the effect of the drop height on the diameter of the crater or the effect of rock size on the depth of the crater. Each member of your group might like to graph different variables.

Discussion

1. Identify the independent and dependent variables in each of your experiments.
2. Write a suitable conclusion to your investigation.

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. **Describe** what comets are made of.
2. **Describe** the asteroid belt.
3. **Explain** the difference between a meteor and a meteorite.
4. **Explain** the difference between a meteor and a meteoroid.

Think

5. **Explain** why the tail of a comet gets larger as it gets closer to the sun.
6. **Explain** how asteroids are different from moons.
7. **Explain** the difference between a planet and a moon.

6.5 The Earth in motion

6.5.1 Day and night

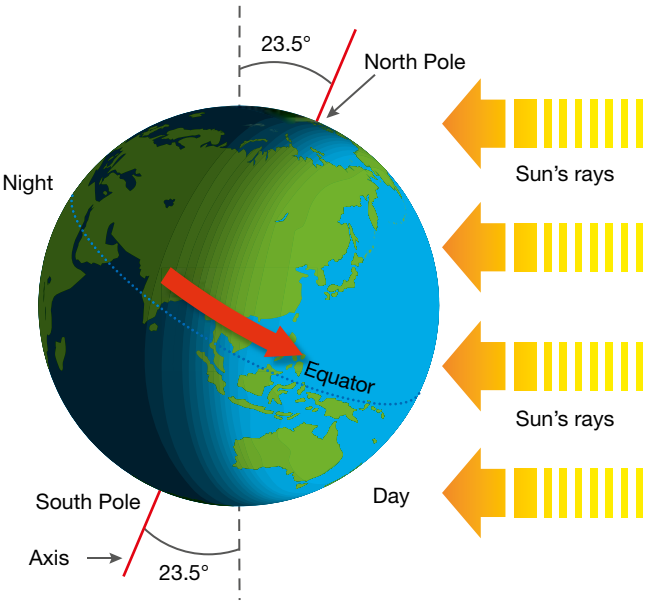
Have you ever wondered why it gets dark or why the sun rises in Sydney before it does in Perth? Why is Australia in the middle of a hot summer in January while Europe experiences a cold winter? These things can all be explained by the movement of the Earth through space.

The Earth's rotation

To us on Earth it seems that the sun rises each day in the east and sets in the west. In fact, the sun doesn't move across the sky at all. It is the Earth that moves — and quite fast, too! People living on the equator are moving at close to 1670 kilometres per hour! We don't sense we are moving as everything around us moves at the same speed.

Like a spinning top, the Earth rotates — spinning from west to east around its axis. The axis of the Earth is an imaginary line drawn from the North Pole to the South Pole, but tilted at an angle of 23.5°. One rotation takes 24 hours. We call the time for a complete rotation one day. As the Earth spins around, first one side and then the other faces the sun and experiences daytime. The side facing away from the sun gets no sunlight, so it experiences night-time.

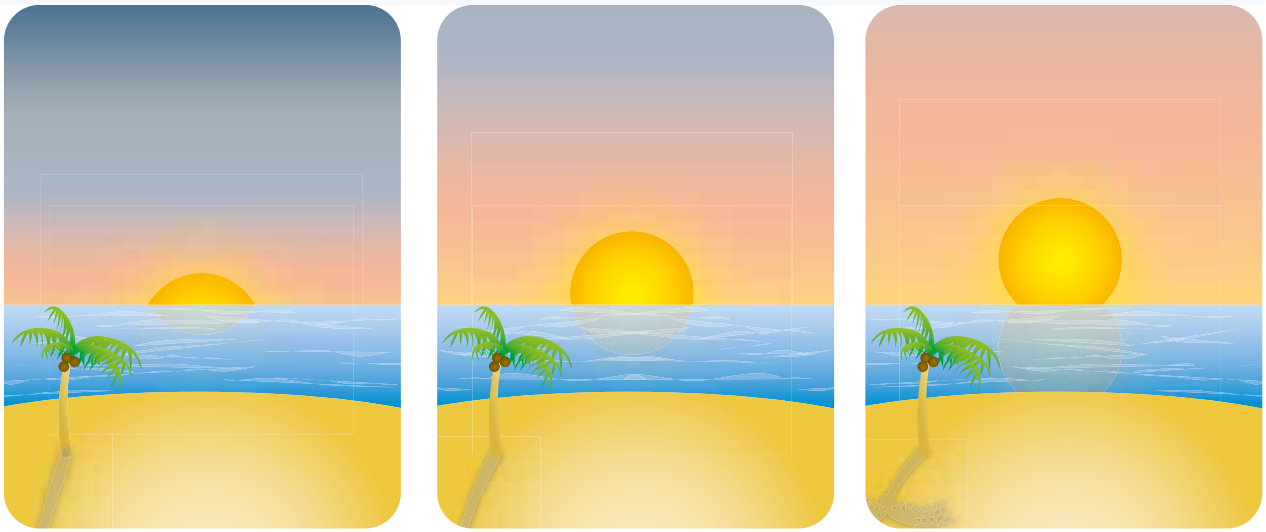
The Earth rotates from west to east. Continents facing the sun are in daylight.



HOW ABOUT THAT!

The Earth is spherical but it is not a perfect sphere. The diameter of the Earth measured across the equator is 12 760 km. However, if you measure the diameter between the two poles, the diameter is shorter by 40 km because the Earth has a slight bulge at the equator.

On the east coast of Australia, the sun rises over the Pacific Ocean.



6 am 6.15 am 6.30 am

The Earth rotates from west to east. Therefore, the sun during the day and the moon, planets and stars during the night seem to move in the other direction, from east to west. Ancient astronomers believed that the Earth was stationary while objects in the sky moved.

Star trails. Stars appear to move in the night sky but it is the Earth that is rotating, as shown in this time-lapse photo.



6.5.2 The Earth in orbit

As well as rotating on its axis, the Earth is travelling through space in orbit around the sun. A gravitational force keeps the Earth in orbit around the sun. The time it takes to complete one revolution of the sun is called a calendar year. The earth rotates 365¼ times in each calendar year and so there are 365¼ days in a year.

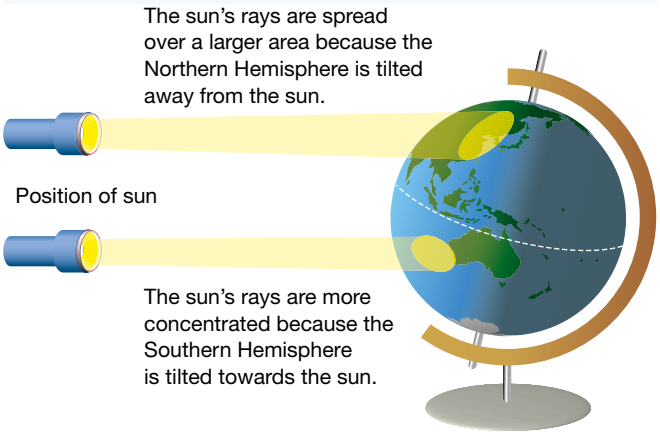
To make the calendar simpler, each year is allocated 365 days, and every fourth year is called a leap year, with an extra day added (29 February), giving a leap year 366 days in total.

The seasons

As the Earth completes its orbit around the sun, the tilt of its axis does not change. It leans to the left or to the right, depending on the direction you are observing the orbit. This means that, during one part of the orbit, one hemisphere is tilted towards the sun while the other hemisphere points away.

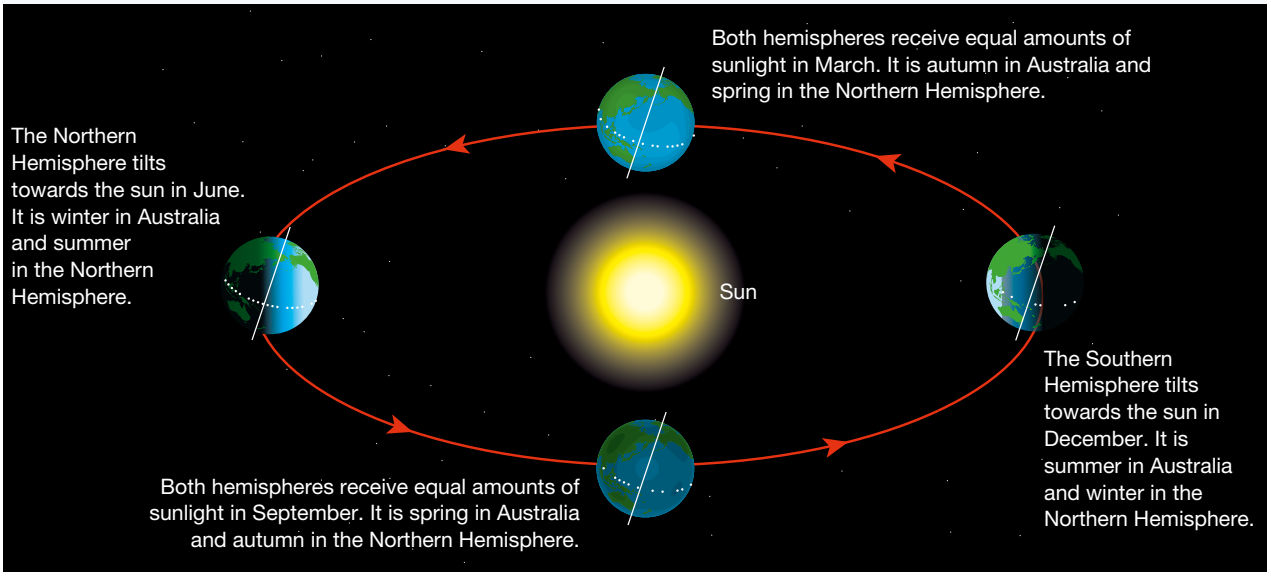
Sunlight hitting the hemisphere that is tilted towards the sun is concentrated over a smaller area and so heats that part of the Earth more. This hemisphere experiences summer. At the same time, the other hemisphere is tilted away from the sun. The sun's rays striking it are spread out over

Simulating winter in the Northern Hemisphere and summer in the Southern Hemisphere using torches



a larger area so this hemisphere heats up less, so the days are colder. This hemisphere experiences winter. When neither hemisphere tilts towards the sun, which happens in autumn and spring, each receives the same amount of the sun's rays. So there is not much difference between, say, a Northern Hemisphere spring and a Southern Hemisphere autumn.

Because of the tilt of the Earth, seasons change as the Earth completes its orbit of the sun.



INVESTIGATION 6.6

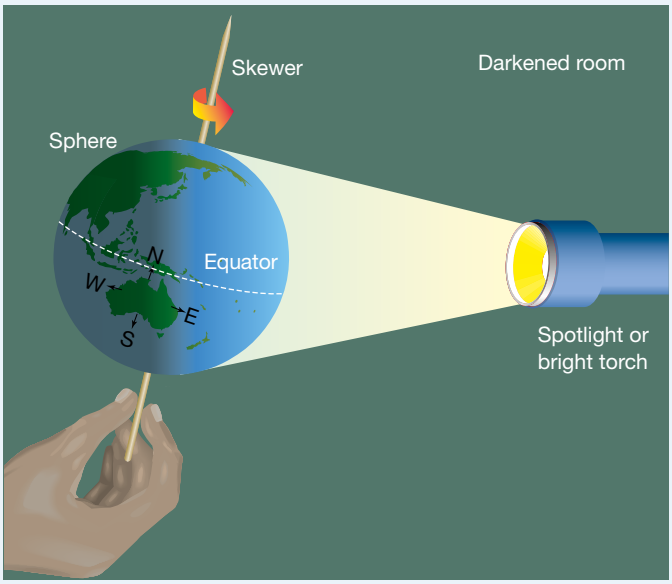
Day and night across the Earth

AIM: To model the day/night cycle

You will need:

polystyrene (or similar) sphere (about the size of a small rockmelon)
metal or wooden skewer
pen
spotlight or bright torch

- Your sphere represents the Earth. Draw a line around the centre to represent the equator. Label the Northern and Southern Hemispheres and mark in the North and South Poles.
- Draw an outline of Australia and Africa on your sphere. Use an atlas to check the positions and approximate shape of each continent. Also note the position of north.
- Mark the four compass directions — north, south, east and west — around the outlines of each continent.
- Gently push a skewer through the centre of your sphere from bottom to top through the 'polar regions'. This skewer represents the Earth's imaginary axis.
- Do this experiment in a darkened room. This will help you see more clearly the contrast between light and dark.



- Turn on the spotlight in a dark room. Its light represents the sun's light. Hold the skewer so it leans a little away from the vertical. This represents the Earth's tilt.
- Turn your sphere very slowly in the light, making sure you keep the skewer slightly tilted all the time. Turn it in an anticlockwise direction (as seen from above). Watch what happens from side on.

Discussion

1. In which direction is the 'Earth' rotating — from east to west or west to east? Check the compass directions you marked on your sphere.
2. In which direction does the 'sun's' light seem to move around the 'Earth'? How does this explain the apparent movement of the sun across the sky?
3. Where is Africa when Australia is lit up? Where is Australia when Africa is lit up? Explain why these continents experience daylight at different times.
4. How does this experiment help to explain why night falls in Perth about two hours later than in Sydney?

INVESTIGATION 6.7

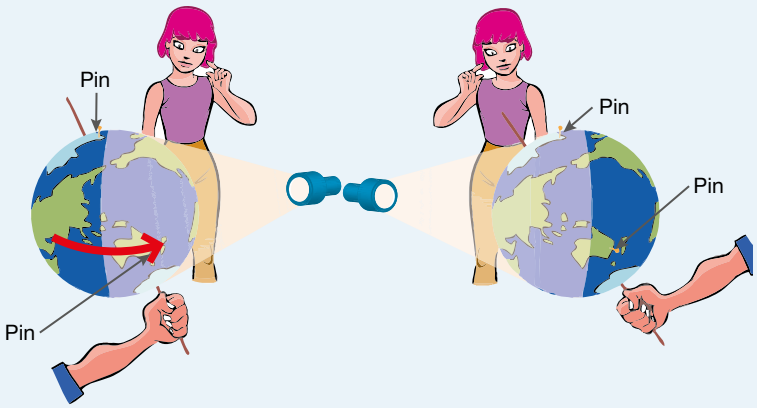
Day length in summer and winter

AIM: To explain why the number of daylight hours varies

You will need:

the equipment used for Investigation 6.6
2 pins with coloured heads

- Do this experiment in a darkened room; this will help you see more clearly the contrast between light and dark.
- Hold the skewer vertically. Push two pins into your sphere — one about where Sydney is and the other directly above it at the top of the sphere, near the skewer.
- Set the torch up in a central place (such as on a table you can move around).
- Stand to the left of the torch. Turn on the torch. Hold the skewer so it leans away to the left from the vertical. The southern half of your sphere should be leaning more towards the light.
- Slowly turn your sphere in the light, making sure you keep the skewer slightly tilted. Turn it in an anticlockwise direction. Observe how long the two locations marked with pins remain in the light.
- Now stand to the right of the torch holding your skewer tilted to the left as before. This time the northern half of your sphere should be leaning more towards the light. Repeat what you did in the previous step.
- Repeat the whole procedure above two more times. The first time, look at what happens at each of the poles. The second time, look at what happens at the equator.



Discussion

1. Which pin comes into the light first when the southern half of the sphere leans towards the light? Ask your partner which pin moves out of the light first.
2. What does this tell you about the number of daylight hours in each hemisphere when the Southern Hemisphere tilts towards the sun?
3. Which pin comes into the light first when the northern half of the sphere leans towards the light? Ask your partner which pin moves out of the light first.
4. What does this tell you about the number of daylight hours in each hemisphere when the Northern Hemisphere tilts towards the sun?
5. What is the approximate length of day and night at the equator in each season?
6. Suggest why the sun never sets at certain times of year at the North and South Poles. Which season is the Southern Hemisphere experiencing when the South Pole has several months of darkness?

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. **Explain** why we experience day and night on Earth.
2. **Explain** why the sun rises in the east and sets in the west.
3. During which season in Australia does the Southern Hemisphere tilt towards the sun?
4. **Explain** why it is warmer on a summer's day than it is on a winter's day.
5. **Explain** why there are 365 days in each year but 366 days in every fourth year.

Think

6. **Explain** why the climate near the equator does not vary much from season to season.
7. **Identify** the season in Australia when:
   (a) it is autumn in England
   (b) it is summer in Canada
   (c) the sun does not set at the South Pole.

Create

8. Present a 3–5 minute lesson to the class using models to explain why we have seasons.
9. Use the **Day, night and time zones** interactivity in the Resources tab to determine whether it is day or night in any location of the world at a specific time.

learnON RESOURCES — ONLINE ONLY

Complete this digital doc: Worksheet 6.3: Night and day (doc-12388)

Complete this digital doc: Worksheet 6.4: Star trails and seasons (doc-12389)

Try out this interactivity: Day, night and time zones (int-0006)

6.6 The moon in motion

6.6.1 Studying the moon

The moon is, by far, the brightest object in the night sky. Its presence and changing appearance when viewed from Earth have raised many questions, inspired myths and legends, shaped our calendar and even determined the dates of some religious holidays.

The moon takes the same time to complete one full rotation around its own axis as it takes to orbit the Earth. For this reason only one face of the moon can be seen from the Earth. The face seen from Earth is much less mountainous and rugged than the other side, probably because it has experienced fewer meteorite impacts.

Unlike the Earth, the moon has no atmosphere. There is no air and there is no water on the surface. It does not experience wind or rain. This means that there is no erosion of its cratered surface.

Profile of the moon

- Natural satellite of the Earth
- Distance from Earth: 385 000 km (three days by spacecraft)
- Diameter at equator: 3475 km (Earth's diameter is 12 750 km)
- Period of orbit around Earth: about $29\frac{1}{2}$ days
- Period of rotation around its own axis: about $29\frac{1}{2}$ days
- Surface gravity: about one-sixth that of Earth
- Surface temperature: ranges from −175 °C in darkness to 125 °C in sunlight

Galileo Galilei is thought to be the first person to have used a telescope to study the moon, planets and stars. He made one of the first telescopes himself in 1610 after hearing rumours of the invention of a magnifying tube in Holland.

While observing the moon's surface, Galileo observed:

- large, dark and flat areas that he called maria (Latin for seas)
- dark shadows that appeared to be made by mountains up to 6 kilometres high
- numerous craters.

Each of these features can be seen in the photograph below left.

The dark, flat areas in this photograph are called 'seas', though no water exists on the surface of the moon. Numerous craters are visible, believed to be the result of meteorite impacts.



HOW ABOUT THAT!

The word 'month' comes from the Old English word mona, meaning 'moon'. In early calendars, a month was the length of time between full 'moons'. This period is called a lunar month. The modern calendar was not developed until the sixteenth century by Pope Gregory XIII. The Islamic, Hebrew and Chinese calendars are still based on the lunar month.

INVESTIGATION 6.8

Observing the moon's surface

AIM: To observe the moon using binoculars or a small telescope

You will need:

binoculars or small telescope

- Observe the moon with a pair of binoculars or a small telescope. The best time to observe the moon is during a quarter moon (when about half of it is visible). Craters and mountains are difficult to see when there is a full moon because they do not cast shadows.
- Try to identify the seas (dark, smooth areas), mountainous areas and craters.
- Sketch and label what you see.

Discussion

1. Which features were easiest to locate?
2. How do you think the craters were formed?

Until 1959, when the first images were transmitted from space, our knowledge of the moon depended on what could be seen through telescopes from Earth. The table at top on next page lists some of the important events that have occurred in the quest for knowledge about the moon.

The most significant event, since Galileo's use of a telescope in 1610 to observe the moon, occurred on 20 July 1969. On that day, astronaut Neil Armstrong stepped down from the lunar landing craft *Eagle* and, as his foot touched the lunar soil, he uttered the memorable words: 'That's one small step for a man, one giant leap for mankind'.

6.6.2 Probing the moon: some important events

Probing the moon: some important events

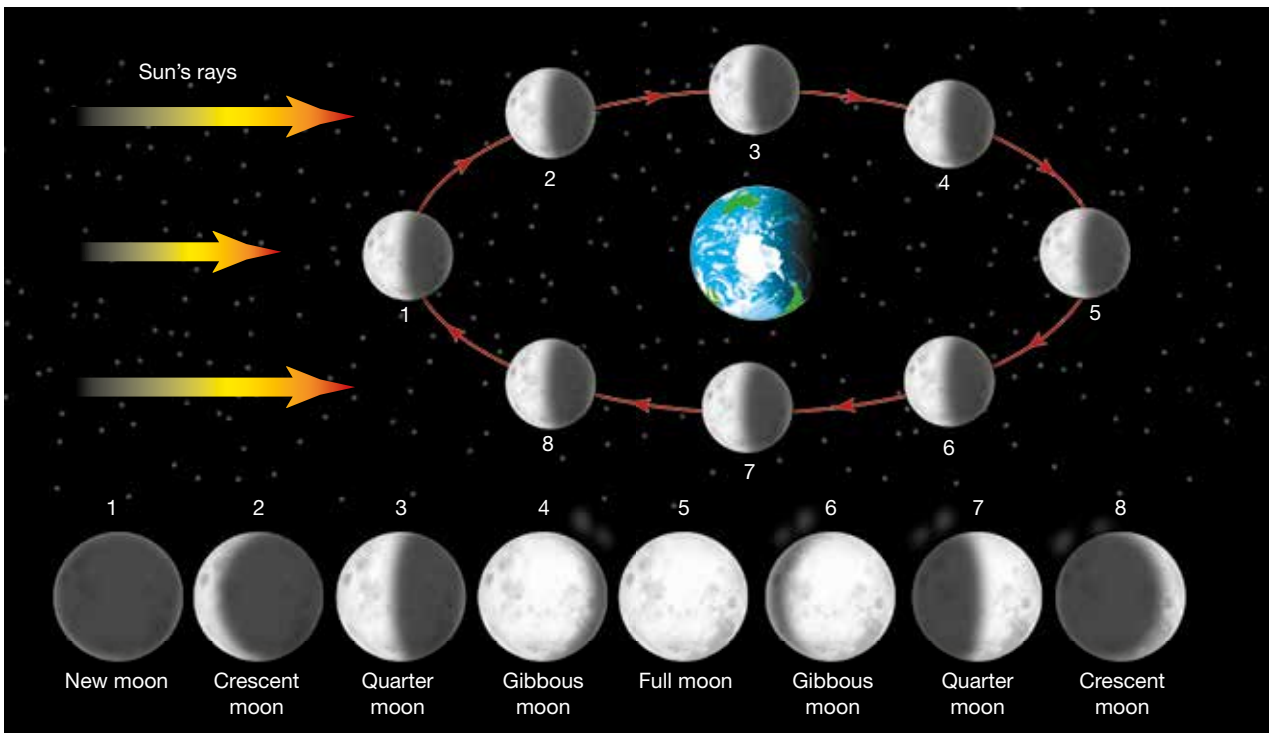
Year	Event
1610	Galileo Galilei used a telescope to observe the moon.
1850s	Astronomers took the first photographs of features of the moon.
1959	*Luna 2* (USSR) became the first space probe to reach the moon when it crashed into the surface.
1959	Space probe *Luna 3* (USSR) provided the first pictures of the previously unseen far side of the moon.
1964	Space probe *Ranger 7* (USA) took the first close-up pictures of the moon.
1966	*Luna 9* (USSR) became the first space probe to make a soft landing on the moon and take pictures from the surface.
1969	*Apollo 11* (USA) carried three astronauts and the lunar lander *Eagle* to and from the moon. Astronauts Neil Armstrong and Buzz Aldrin became the first humans to walk on the moon. They spent three hours collecting soil and rocks, performing experiments and setting up equipment for further experiments.
1969–1972	Apollo missions 12 and 14–17 (USA) successfully reached the moon, enabling more experiments to be completed. *Apollo 13* failed, stranding the three astronauts in space. The astronauts were able to return safely to Earth by using the fuel and oxygen stored in their lunar lander.

6.6.3 Phases of the moon

The moon is visible from Earth only because it reflects light from the sun. As the moon orbits the Earth, it rotates so that the same side of the moon always faces the Earth. Once in each lunar cycle, when viewed at night, this entire side of the moon is completely bathed in sunlight; this is called a full moon.

As the moon continues its orbit of the Earth, less of the lit face of the moon is visible from the Earth, leading to a quarter moon. Eventually, the near side is completely dark again and there is another new moon, and so the sequence continues. During the period between a new moon and a full moon, the moon is said to be waxing. As the phases move from full moon to new moon, it is said to be waning.

The diagram below shows how the phases change during the $29\frac{1}{2}$-day lunar cycle, the period between one new moon and the next.



INVESTIGATION 6.9

Modelling the phases of the moon

AIM: To model the phases of the moon

You will need:

projector or bright torch
large, light-coloured ball

- Select one student to act as the Earth and another to hold the ball representing the moon.
- Darken the room and aim the projector or torch (the sun) at the ball (the moon). The student holding the 'moon' walks around the 'Earth' slowly in an anticlockwise direction, holding the same side towards the 'Earth'.
- Try to identify each of the eight phases of the moon, as they are seen by the person representing the Earth. Stop rotating briefly when each of the phases is identified so that the positions of the 'sun', 'Earth' and 'moon' can be recorded in a diagram.



Discussion

1. Sketch a plan view to show the positions of the 'sun', 'Earth' and 'moon' that result in:
   (a) a full moon
   (b) a gibbous moon
   (c) a quarter moon
   (d) a crescent moon
   (e) a new moon.
2. Describe the positions of the sun, Earth and moon when there is:
   (a) a full moon
   (b) a new moon.

INVESTIGATION 6.10

The changing moon

AIM: To observe the phases of the moon and relate these to the position of the sun

- Copy the start of the table below into your notebook.
- Observe the moon every third or fourth evening over a period of at least two weeks. Observations over one whole month would be best. Try to make your observations as close to sunset as possible so that you know where the sun is.
- Record the date, the time, and the shape of the sunlit part of the moon.
- Each time you make an observation, make a comment about the position of the sun compared with the moon, and why the moon has the shape that you have observed.

Observing the phases of the moon

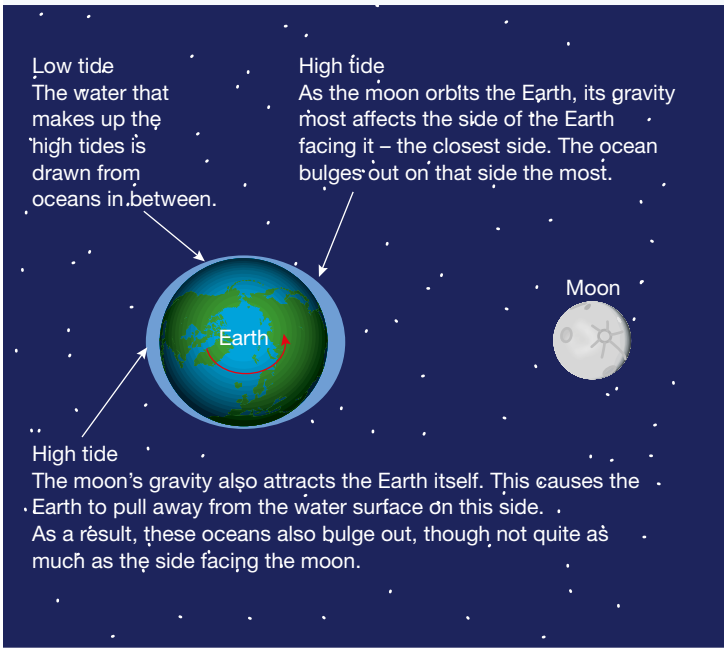
Date	Time	Shape of moon	Comment about position of sun and the shape of the moon
			

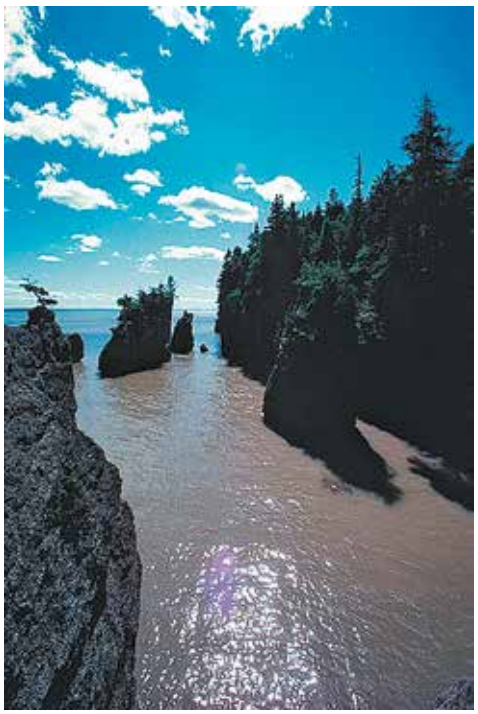
6.6.4 Ocean tides — ebb and flow

Each day, the waters of the Earth's oceans rise and fall against the coastlines of islands and continents. These changes in sea level are called tides. They are caused by the **gravitational attraction** of the moon and, to a lesser extent, the sun on the Earth's oceans.

The gravitational pull of the moon on the water on Earth's surface causes the oceans facing it to bulge outwards, resulting in a high tide. A second, smaller bulge develops on the side of the Earth facing away from the moon because the Earth is also being pulled towards the moon and away from the water on the far side. Since the Earth is rotating while this is happening, two high tides occur each day.

Looking down on the Earth from above the North Pole. As the Earth rotates, different places experience high tide.





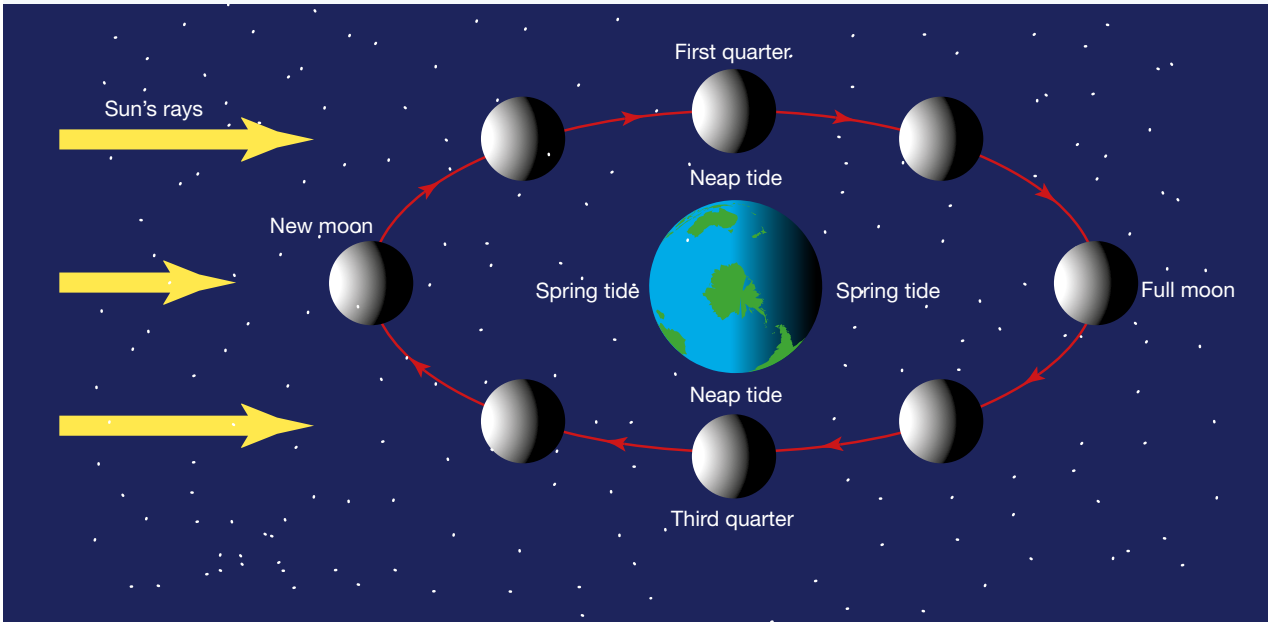
High and low tide in the Bay of Fundy on the east coast of North America. Its **tidal range** — over 16 m — is the biggest in the world. The bay has a very wide mouth that allows a lot of water to rush in as the tide rises. But the bay gets much narrower further inland. The huge volume of water has nowhere to go but up!



6.6.5 Spring and neap tides

The sun also plays a role in the pattern of tides, although it is not as significant as that of the moon. While the **mass** of the moon is 27 million times less than the sun, its gravitational pull on the Earth is greater than that of the sun because it is so much closer to Earth. It is important to remember that gravity is a force of attraction between any two bodies in the universe that have mass. The size of this force depends not only on the mass of the two bodies but also on how close they are to one another.

Each month there are two spring tides and two neap tides during a full moon and a new moon.



Twice each month, the moon, sun and Earth line up. This occurs when there is a full moon and at the time of a new moon. At these times, the gravitational pull on the Earth and its waters is much stronger as the gravity of the sun and moon combine. Hence, the ocean bulges contain even more water. This means the tidal range is much greater. These tides are called **spring tides**.

About seven days after a spring tide, the moon and sun are at right angles to each other with respect to the Earth. In this position, their forces of gravity work against one another, rather than together. So, the tidal range is narrow. These tides are called **neap tides**.

INVESTIGATION 6.11

Tide data

AIM: To plot data on tide height and determine the tidal pattern

You will need:

graph paper

- The following data show the tide heights in Manly, NSW at two-hourly intervals.

Date	Time	Tide height (m)	Date	Time	Tide height (m)
Wed. 28 Nov.	5 am	1.0	Thu. 29 Nov. (Continued)	5 am	0.4
	7 am	1.5		7 am	0.9
	9 am	1.7		9 am	1.2
	11 am	1.3		11 am	1.2
	1 pm	0.7		1 pm	0.7
	3 pm	0.5		3 pm	0.4
	5 pm	0.8		5 pm	0.5
	7 pm	1.3		7 pm	1.1
	9 pm	1.7		9 pm	1.3
	11 pm	1.5		11 pm	1.2
Thu. 29 Nov.	1 am	0.8	Fri. 30 Nov.	1 am	0.8
	3 am	0.4		3 am	0.5

- Plot the data on a sheet of graph paper, showing the tide heights on the vertical axis and the date and time on the horizontal axis.
- Draw a smooth curve of best fit based on your data.

Discussion

1. What is the time and height of the high tide on Thursday morning?
2. How often do a high tide and a low tide occur?
3. Use a labelled diagram showing the Earth and moon to explain why this location experiences a low tide late Wednesday afternoon.

6.6 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. **Identify** the large, dark, flat areas on the moon that are visible from Earth.
2. **Identify** the phase of the moon that we see when:
   (a) the Earth is between the sun and the moon
   (b) the moon is between the sun and the Earth.
3. How many days are there between one new moon and the next?
4. **Explain** why the moon has a stronger gravitational pull on Earth than the sun.
5. With the aid of a diagram, **distinguish** between a spring tide and a neap tide.

Think

6. **Explain** why there are more craters on the moon than the Earth, even though the Earth is a bigger target.
7. **Explain** why we never see the far side of the moon.
8. As Neil Armstrong stepped down from the lunar landing craft onto the lunar soil, his now famous words were heard by millions of people watching the event live on television. **Propose** why this step was such a 'giant leap for mankind'.
9. What sort of tide occurs when there is a full moon? **Explain**.
10. If the height of the highest tide on a particular day was 6.5 m and the tidal range was 4.2 m, **calculate** the height of the lowest tide.
11. **Deduce** why one high tide on any given day is always greater than the other one.

Create

12. Design a role-play involving at least four people to clarify how the movement of the Earth around the sun, and the moon around the Earth, cause tides. A narrator could be used to give a commentary of the role-play.
13. Use the **Tides** interactivity in the Resources tab to investigate tides.

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Complete this digital doc: Worksheet 6.5: The moon (doc-12390)

Try out this interactivity: Tides (int-0225)

6.7 Lunar and solar eclipses

6.7.1 Lunar eclipses

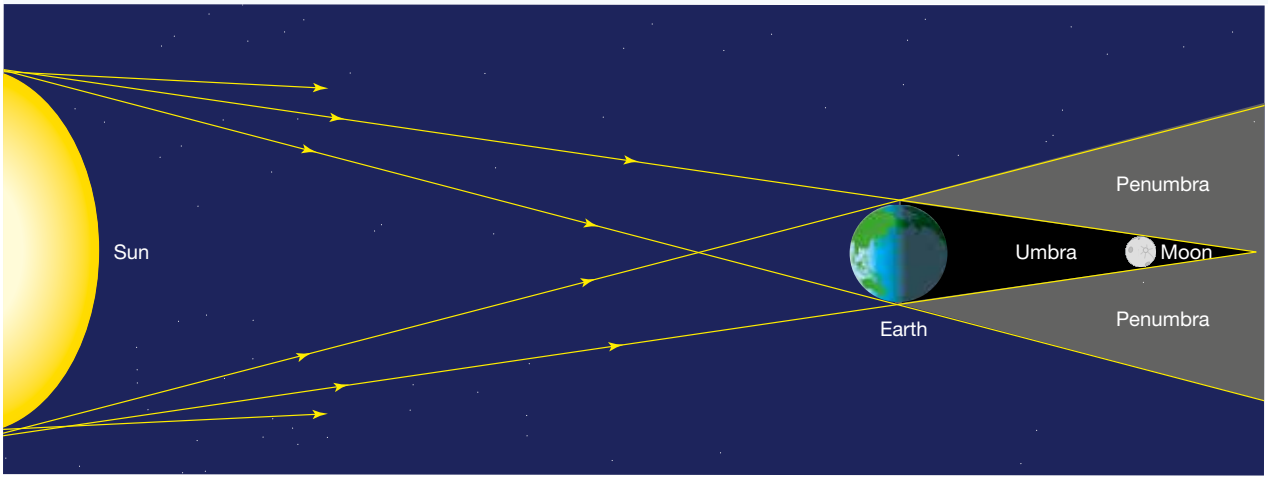
Lunar eclipses occur when the moon moves into the Earth's shadow. During a **total lunar eclipse**, the moon and Earth are lined up so that the whole of the moon is in shadow for a while. If they are not completely aligned, only a part of the moon will be in shadow; this is called a **partial lunar eclipse**.

During a total lunar eclipse, the moon looks as though it goes through all its different phases in one night. However, this is not the case; in fact, it is a full moon all night long. Lunar eclipses can occur only when the Earth is between the sun and the moon, and that can happen only during a full moon.

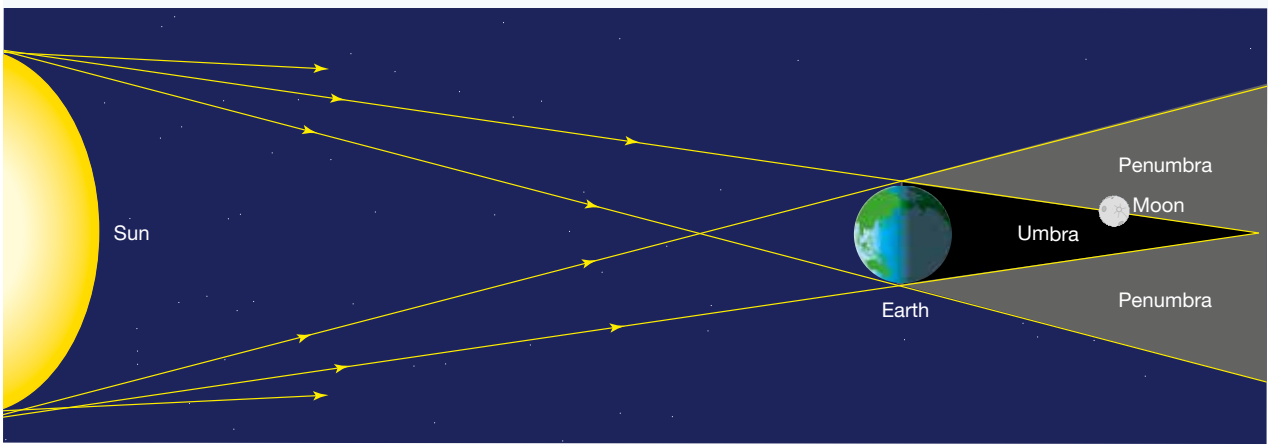
Why doesn't an eclipse occur every full moon? The sun, Earth and moon line up exactly only a few times a year. If a straight line was drawn between the sun and the Earth, the moon's orbit is usually offset from it by about 5°. So, at most times when there is a full moon, the moon misses the Earth's shadow — it passes above or below it.

The moon usually looks white because it reflects white light from the sun; however, during an eclipse, the moon takes on a red tinge. This is because, during a total eclipse, the only light that reaches the moon first passes around the edges of the Earth and so has passed through the Earth's atmosphere. The Earth's atmosphere scatters the blue light from the sun leaving mainly red light to illuminate the dimly lit moon.

Total lunar eclipse



Partial lunar eclipse



The Earth's shadow makes the moon appear to change phases during a total lunar eclipse. Note the red tinge of the moon at the height of the eclipse.



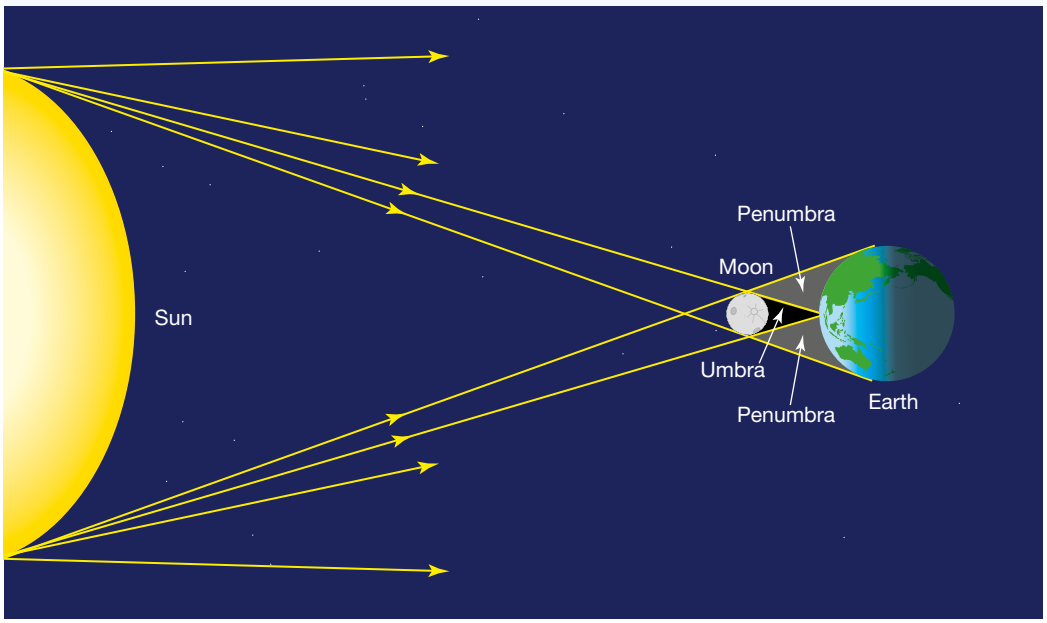
6.7.2 Solar eclipses

Solar eclipses occur when the moon lies between the sun and the Earth. This means that the moon's shadow falls on the Earth. People on Earth within the **umbra** of the moon's shadow see a total eclipse of the sun. Those within the **penumbra** see a **partial solar eclipse**.

Total solar eclipses are not seen often as the moon casts only a narrow shadow on Earth. The umbra may be only about 100 km wide. It may fall in the middle of an ocean. It may even miss the Earth altogether.

CAUTION: You must NEVER look directly at an eclipse of the sun — even a partial eclipse. You could permanently damage your eyes. Sunglasses will not protect you.

Total and partial solar eclipses



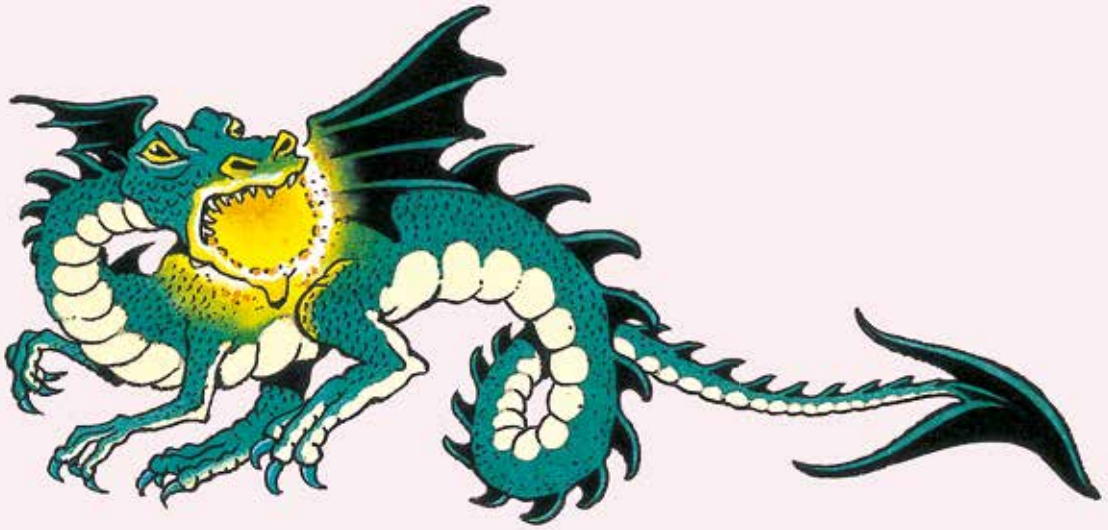
A total solar eclipse — the sun's light is blocked as the moon passes in front of it. The sun's corona is visible in the middle photo.



During a total eclipse, the area within the umbra on Earth becomes quite dark for a few minutes. You might even see some stars during the day! While the sun disappears from view, its **corona**, a faint halo around its surface, can still be seen. The corona is not normally seen because the sun is so bright.

HOW ABOUT THAT!

The ancient Chinese believed that solar eclipses occurred when a giant dragon ate the sun. They thought that if they made enough noise they could frighten the dragon. The frightened dragon would then spit the sun out, bringing daylight back.



INVESTIGATION 6.12

Modelling solar and lunar eclipses

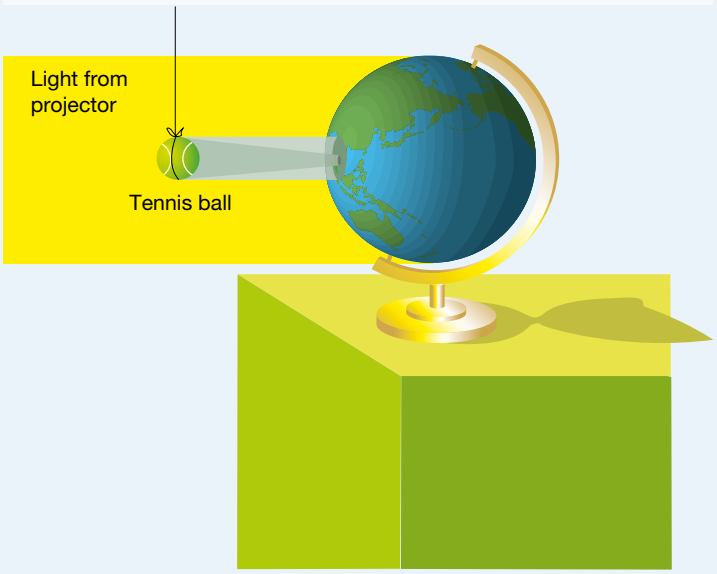
AIM: To model a solar and a lunar eclipse

You will need:

projector
globe
tennis ball attached to string

- Darken the room and aim a beam of light at the globe.
- To simulate a solar eclipse, suspend the tennis ball (moon) between the projector (sun) and the globe (Earth) as shown at right. Ensure that you keep your own shadow off the globe.
- Rotate the globe a little (think carefully about which way to turn it) and note what happens to the shadow.
- To simulate a lunar eclipse, move the tennis ball to the opposite side of the globe from the projector. Suspend it so that it is partly in the shadow of the globe.

Modelling a solar eclipse



Discussion

1. Draw a diagram to show the initial positions of the Earth, moon and sun in your model of a solar eclipse.
2. During which phase of the moon does a solar eclipse occur?
3. When you rotate the globe, does the shadow move from east to west or from west to east?
4. Draw a diagram showing the positions of the Earth, moon and sun in your lunar eclipse model.
5. During which phase of the moon does a lunar eclipse occur?

6.7 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. **Outline** the difference between a solar eclipse and a lunar eclipse.
2. **Explain** why you must never look directly at a solar eclipse.

Think

3. **Explain** why total solar eclipses are much less frequent than partial solar eclipses.
4. **Propose** why a total lunar eclipse occurs only when there is a full moon, and why a solar eclipse occurs only when there is a new moon.
5. Test your knowledge of solar and lunar eclipses by completing the **Eclipses** interactivity in the Resources tab.

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Complete this digital doc: Worksheet 6.6: Eclipses (doc-12391)

Try out this interactivity: Eclipses (int-0207)

6.8 Early ideas in astronomy

Science as a human endeavour

6.8.1 Indigenous Australian astronomy

Astronomy is the study of stars, planets and other objects that make up the universe. The history of astronomy goes back several thousand years. Almost all ancient cultures had stories about how the universe was created, what it was like, who created it, and how the Earth and humans got here.

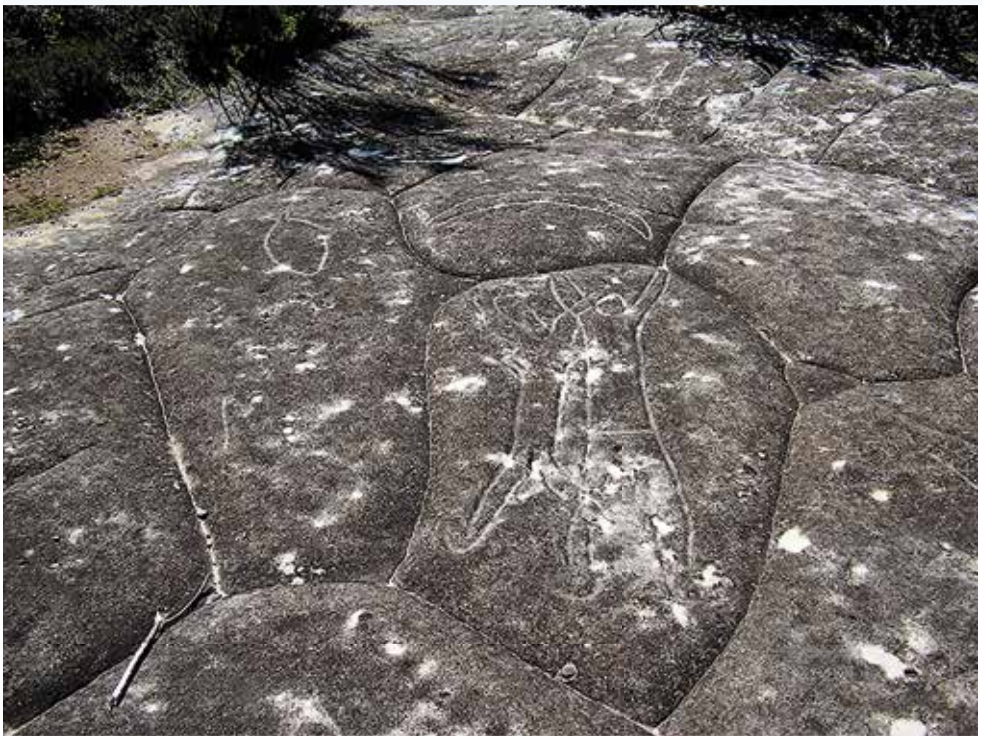
The Yolngu people of Arnhem Land explain the sunrise, sunset and movement of the sun through the sky in terms of Walu, the Sun-woman. Walu lights a fire each morning, which we see as the dawn. Holding her torch, she travels across the sky from east to west. At the end of her journey to the western horizon, she goes underground for her return journey east, back to her starting point at her morning camp. Walu uses red ochre to decorate her face and body; when some of the red dust falls onto the clouds, this creates the red sunrise and red sunset.

The Yolngu people explain the phases of the moon through the story of Ngalindi and his wives. At the time of the full moon, Ngalindi is a fat, lazy man. His wives punish him by attacking him with an axe, and he is seen as a waning moon as parts of him are chopped off. Unable to escape his wives, Ngalindi dies of his wounds, and this is the time of the new moon. He rises from the dead after three days and is seen as the waxing moon as he again grows round and fat. Two weeks later, his wives punish him again, and the cycle repeats.

HOW ABOUT THAT!

Other dreamtime stories show that the Yolngu people knew about the relationship between tides and the moon's motion. They explain that, at high tide, water fills the moon as it rises. When the water flows back out of the moon, the tides fall. The moon is empty for three days before the tide rises again, when the moon is again filled with water.

Among thousands of beautiful rock engravings in Ku-ring-gai Chase National Park in Sydney's north is this one (below), believed by some scientists to represent two figures below a crescent moon (right).





A dreamtime story of the Warlpiri people explains solar and lunar eclipses. When the Sun-woman and Moon-man embrace, the Sun-woman is covered over and this is seen as a solar eclipse. At other times they argue and the Moon-man is hidden from view as the Sun-woman chases and threatens him. This is seen as a lunar eclipse. These stories show that the Warlpiri people understood that eclipses relate to the motion of the sun and moon across the sky; they occur when their paths meet.

6.8.2 Incan astronomy

For about 300 years, from the 1200s until the Spanish conquistadors invaded in the 1500s, much of South America around Peru was ruled by the Incan empire. The Incas watched celestial events with the naked eye to develop a wide range of astronomical ideas.

At Cusco, the astronomical centre of their empire, the Inca constructed a series of stone towers to mark the points of sunrise and sunset on important days. These included the summer solstice (longest day of the year) and the winter solstice (shortest day of the year). The Incas created an accurate annual calendar based on the positions at which the moon rose and set on the horizon, as well as observations of the phases of the moon.

Rock engravings at Ngaut Ngaut, South Australia, which are said to represent lunar cycles. There are many examples like this throughout Australia that suggest that astronomy is an important part of many Australian Aboriginal cultures.



The Incas had a deep knowledge of the stars and constellations, which they observed and named. For example, the Incan name for the bright stars of the Milky Way was **mayu**, meaning river. This celestial river was said to join up with the Urubamba River in the waters of a great cosmic sea that encircled the Earth. The Incas believed that the celestial river, the Milky Way, was the source of rain on Earth as it passed through the night sky.

The Southern Cross constellation contained the most important stars to the Incas since it could be used to show the points of the compass, with the most distant star pointing south when visible in the sky.

Most historians agree that the Incans had a calendar based on the observation of the sun and the moon and their relationship to the stars. Names of 12 lunar months are recorded.



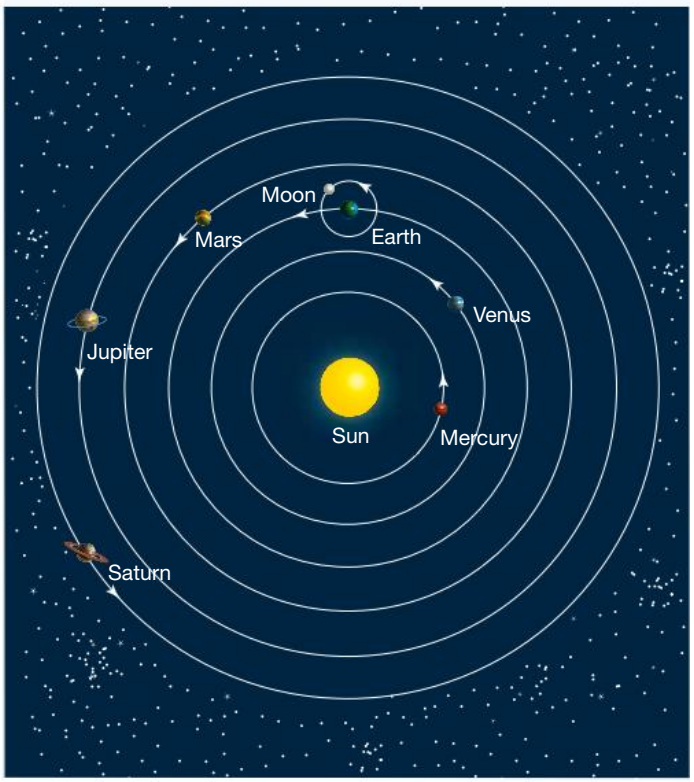
6.8.3 Ancient Greek astronomy

Much of our current scientific knowledge was developed in Europe, so it has a Western influence. The ancient Greeks provided many of the early ideas from which modern astronomy was developed. Actually, the word 'astronomy' comes from Greek terms for 'law and order'. The Greeks were not the first culture to study the night sky but their ideas were widely accepted throughout Europe for hundreds of years.

The Greeks discovered that the Earth was spherical; the Greek philosopher Eratosthenes measured the circumference of the Earth to within about 300 kilometres of the true value. In the fourth century BC, Aristotle was one of the most influential philosophers in Greece. He believed that the sun and moon revolved around the Earth, which was the centre of the universe. He used this philosophy to develop what we call a geocentric model. This model was easily accepted at the time as people who studied the night sky saw celestial bodies passing over the Earth.

In the following century, Aristarchus developed his heliocentric model. He stated that the sun was at the centre of the universe and the planets, including the Earth, orbited it along circular paths. He noted that, once a day, the

Aristarchus's heliocentric model



moon revolved around the Earth and the Earth rotated on its axis.

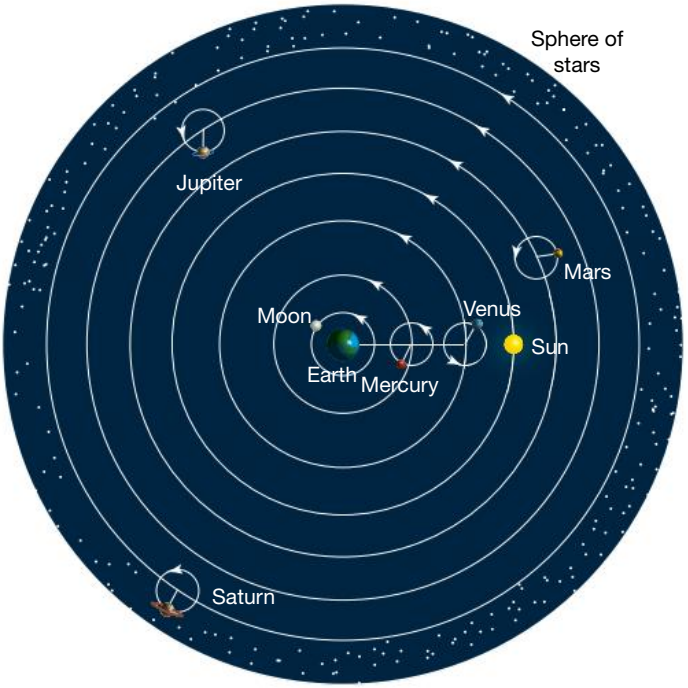
Aristarchus's model did not gain wide acceptance until Copernicus redeveloped it 2000 years later. This sun-centred theory would have defied common sense at the time because we do not feel the Earth spinning or moving through space.

Hipparchus (190–120 BC) was the greatest astronomer of his time. He made extensive observations of star positions and is credited by some with the production of the first known catalogue of stars.

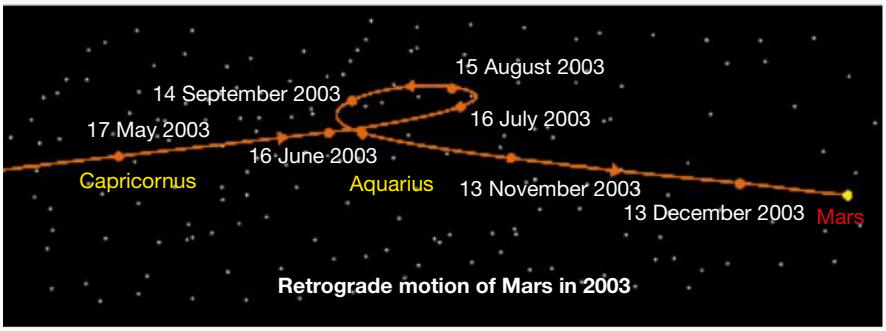
Like Aristotle, Claudius Ptolemy (AD 85–165) proposed a geocentric model of the universe. He maintained that the five satellites discovered up until then, namely Mercury, Venus, Mars, Jupiter and Saturn, together with the moon and the sun, revolved around the Earth.

When observing the planets over many nights, the positions of some of the planets appeared to travel backwards relative to the other planets or the background stars; this is called retrograde motion. Previous models of the solar system could not explain this observation. Ptolemy suggested that the planets travelled in small circular orbits (epicycles), while also orbiting around the Earth, and that the stars occupied the outermost circle.

Ptolemy's model of planetary motion included the idea of epicycles.



From July to September 2003, the planet Mars appeared to travel backwards relative to the stars in the background. This is an example of retrograde motion.



Claudius Ptolemy (AD 85–165), the last of the great classical astronomers



6.8.4 Early Middle Eastern astronomy

Middle Eastern astronomy in the ninth to thirteenth centuries had a significant influence on European astronomy that flourished after the Middle Ages. A significant number of stars in the sky, such as Aldebaran and Altair, are still referred to by their Arabic names.

Al-Battani (868–929 AD) born in present-day Turkey, made many contributions to astronomy. Rather than using geometric methods, as Ptolemy had done, Al-Battani used trigonometry to analyse the ecliptic plane, the plane swept out by the Earth as it orbits the sun. Using this approach he accurately calculated the length of the year as 365 days, 5 hours, 48 minutes and 24 seconds, and the angle of the Earth's tilt based on

the angle to the ecliptic plane as 23.35°. His calculations are very close to the values accepted today, over a thousand years later. From his understanding of the Earth's movement around the sun, Al-Battani even predicted the possibility of solar eclipses.

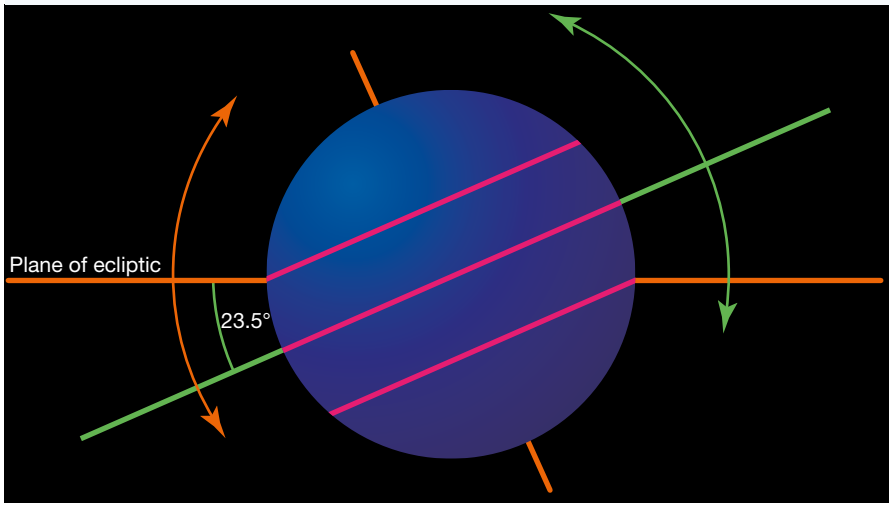
Al-Biruni (973–1050 AD) lived in a region that is within Afghanistan today. He accepted the idea that the Earth rotated on its axis and he made accurate calculations of latitudes and longitudes. He calculated the Earth's circumference, and accurately determined the direction of Mecca from any point on the globe.

Al-Biruni rejected Aristotle's view of heavenly bodies moving only in circular orbits, and considered the possibility of them moving in elliptical orbits. At the time of Al-Biruni, it was well accepted that the Earth was in the centre of the known universe, and that the planets, stars and sun revolved around it. Al-Biruni proposed, 600 years before Galileo, that the Earth rotates on its axis daily and moves around the sun over the course of a year. He was probably the first to understand why the sun never sets in the North or South Pole.

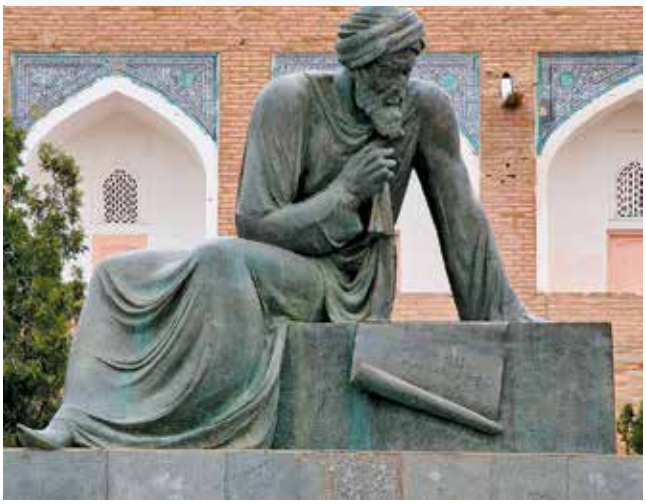
Omar Khayyam (1048–1131) was born in Persia, a region that today includes Iran. During his lifetime, Khayyam was well regarded as a mathematician and an astronomer. He was invited by the Sultan to reform the Persian calendar; there was dissatisfaction because it did not keep step with the seasons, as it was synchronised to the lunar cycle. A lunar year of 354 days, while acceptable to a desert nomad people, proved to be unworkable for the settled, agricultural societies that had developed.

Khayyam helped to develop the Jalali calendar, which remained in use across the Persian region from the eleventh to the twentieth centuries. This calendar begins each year on 21 March, the beginning of spring in the Northern Hemisphere (also called the vernal equinox), as determined precisely by astronomical observations from Tehran. This synchronised

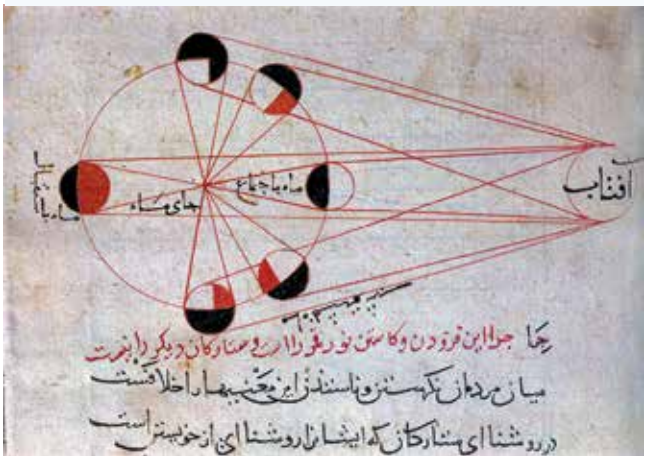
In the tenth century, Al-Battani accurately calculated the angle of the Earth's tilt using the plane of the ecliptic.



Statue commemorating the Middle Eastern astronomer Al-Biruni in Tehran, Iran

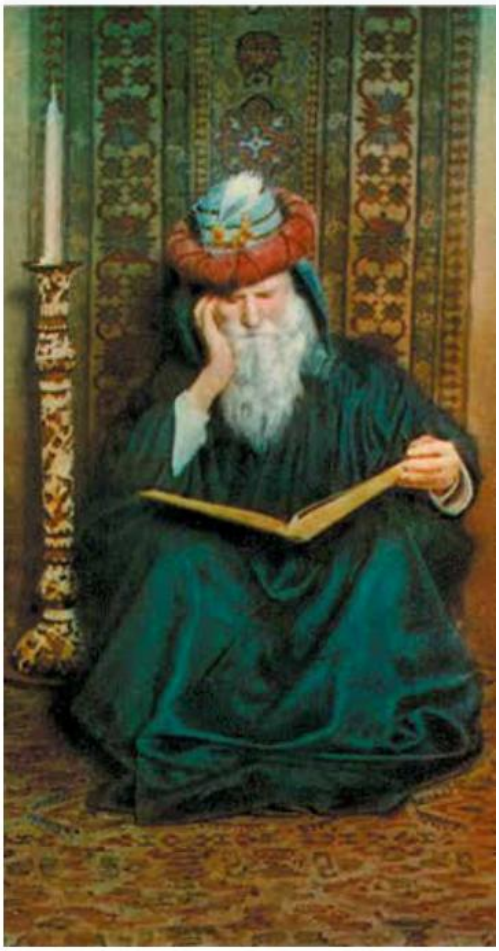


A Persian manuscript with a design by Al-Biruni that explains the moon's eclipses. He observed the lunar eclipse of 17 September 1019 and recorded the exact latitudes of the stars.



the calendar with the solar year, making it more accurate than the Gregorian calendar used in the West. In fact, the Jalali calendar had an error of one day in 3770 years whereas the Gregorian calendar had an error of one day every 3330 years. Because months were based on precise positions of the sun, seasonal drift never exceeded one day, and there was no need for a leap year in the Jalali calendar. However, this calendar required accurate calculations of the movement of the sun so it had to be redeveloped each year; therefore, it was less practical than the Gregorian calendar.

A depiction of Omar Khayyam

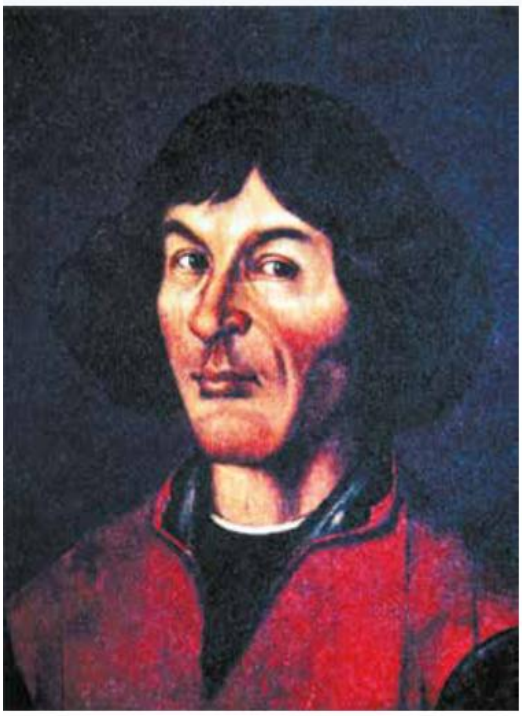


6.8.5 Renaissance astronomy

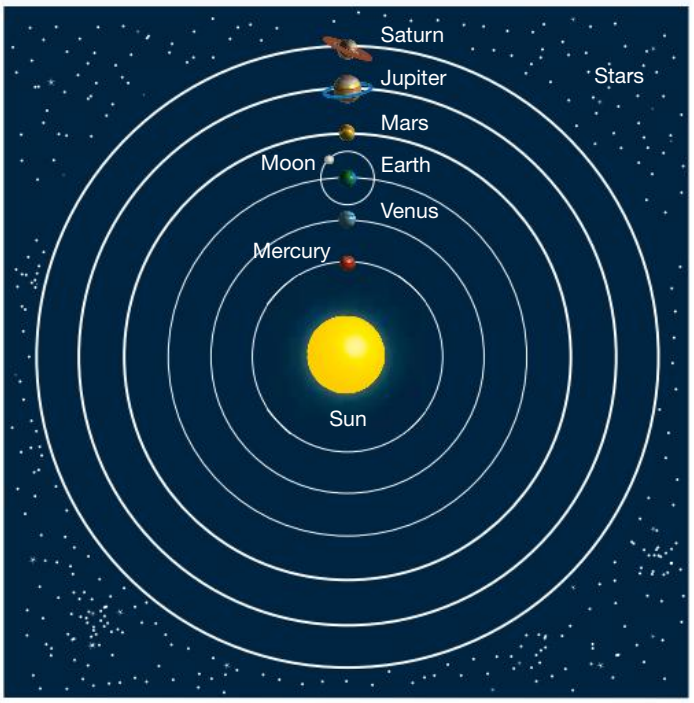
The Renaissance was the period of European history after the Middle Ages from the 1400s to the middle 1600s. It was a period of great scientific advancement in Europe in many areas including astronomy. Nicolaus Copernicus (1473–1543) was a Polish astronomer who, like the ancient Greek Aristarchus, proposed that the sun is stationary and is at the centre of the universe.

On what evidence did Copernicus reject Ptolemy's geocentric model of the solar system? The crossing of Jupiter and Saturn in 1504 observed by Copernicus differed by 10 days from the prediction based on Ptolemy's work. Copernicus reasoned that a valid model should be able to make correct astronomical predictions. He also rejected Ptolemy's idea of epicycles to explain what appeared to be reverse motion of some of the planets. Copernicus's theory, a heliocentric

Nicolaus Copernicus



Copernicus's heliocentric model



model of the solar system, proposed that the Earth rotated on its axis once daily and orbited around the sun once a year. He argued that the planets orbit the sun. To explain the retrograde motion of planets, he suggested that the greater the radius of a planet's orbit, the longer it took for the planet to orbit around the sun. While the Copernican model provided a plausible model to explain the apparent motion of stars and planets in the night sky, it proved to be no more accurate in predicting the position of planets than Ptolemy's model. In fact, most sixteenth-century astronomers could not accept the concept of a moving Earth, and so the core ideas of his model were largely rejected.

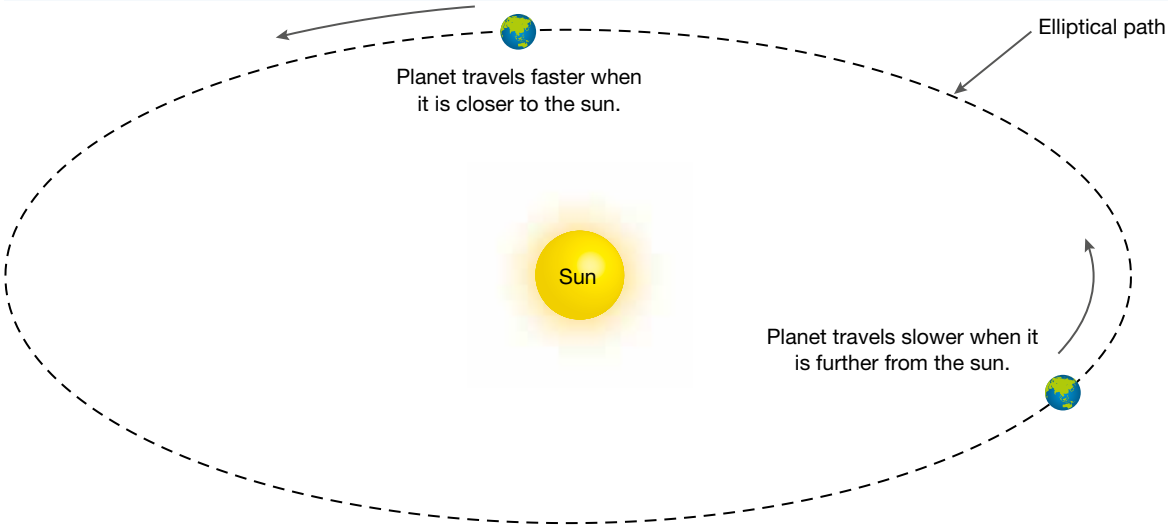
Johannes Kepler



Dutch astronomer Johannes Kepler (1571–1630) supported Copernicus's heliocentric model of the solar system and applied mathematics to the observations of astronomers who preceded him. Kepler abandoned the idea that planets travelled in circular orbits at a constant speed as it proved inaccurate in predicting the positions of the planets. Instead he proposed three laws to explain the motion of the planets in orbit around the sun. The first two were published in 1609 in his work *Astronomica nova* (New Astronomy).

In Kepler's first law, he described the motion of planets as ellipses. (*Note:* In the diagram below, the flatness of the ellipse has been exaggerated.) Kepler's second law explains how the speed of an orbiting planet depends on its position in the elliptical orbit. Kepler's third law describes how planets more distant from the sun take longer to orbit the sun.

Kepler's laws of planetary motion are based on elliptical planetary orbits.



Galileo Galilei (1564–1642) of Italy was originally a professor of mathematics but, by the time of his death, he had became one of the most influential astronomers of the Renaissance.

When Galileo heard about a new optical device, the telescope, in 1609 he quickly built his own version. He then used it and, later, more sophisticated telescopes to systematically study the night sky. He observed the moon and described the lunar surface as uneven, with craters and mountains, for the first time ever.

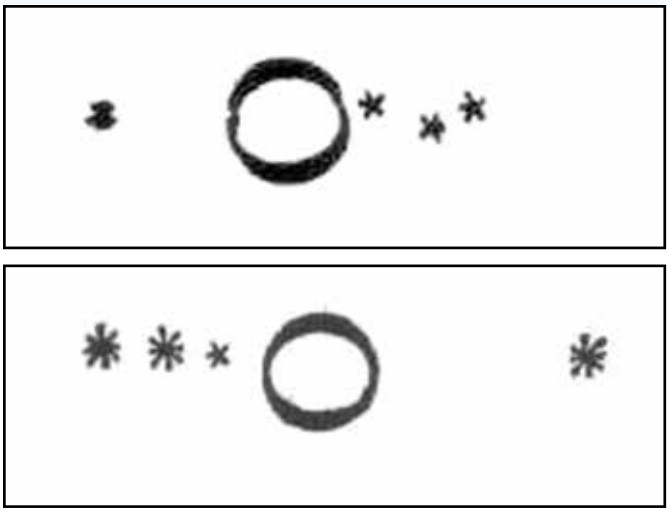
Galileo's observations of the planet Jupiter over successive nights revealed four star-like objects in a line with it. The objects moved from night to night, sometimes disappearing behind or in front of the planet. Galileo correctly inferred that these objects were moons of Jupiter and orbited it just as our moon orbits Earth. Today, these four moons are known as the satellites Io, Europa, Ganymede and Callisto. For the first time, objects had been observed orbiting another planet, thus weakening the hold of Ptolemy's model. The Earth was clearly seen not to be at the centre of all planetary motion.

Galileo's published works contradicted the geocentric view of the universe put forward by Aristotle and Ptolemy and conflicted with powerful authorities in the church. Eventually he was forced to publicly recant his belief in the Copernican system and he lived out his life under house arrest working on a better understanding of the physics of moving objects. While Galileo did not propose his own model of the universe, his observational, experimental and theoretical work provided the evidence that eventually led to rejection of the Aristotelian–Ptolemaic geocentric model of the universe.

Galileo Galilei



The moons of Jupiter as drawn by Galileo on successive nights



6.8 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. How do the Yolngu people of Arnhem Land **explain** the existence of sunrise and sunset?
2. Besides dreamtime stories that still survive today, what other evidence is there that Aboriginal peoples studied the night sky?
3. The Incan calendar, like our own, is based on astronomy. **Outline** the information used to help create such a calendar.
4. **Explain** why a geocentric model of the solar system would have made much more sense to early astronomers than a heliocentric one.
5. **Describe** Al-Battani's contribution to astronomy.
6. Why was Ptolemy's model of the solar system an improvement on previous models?

Think

7. **Describe** the limitations that ancient cultures had on their study of the night sky and **outline** the conclusions that they drew.
8. What observations suggested to Renaissance astronomers that a heliocentric model of the solar system must be correct?
9. **Explain** why Galileo's ideas were so controversial at the time.

Discussion

10. During the Renaissance, new theories about our solar system developed rapidly and previous ones were rejected. In science, why are existing theories replaced by new ones?

Create

11. Create your own dreamtime story to **explain** one of the following phenomena.
    - Tides
    - Sunrise and sunset
    - Eclipses
    - The movement of stars and planets in the night sky

Investigate

12. Research the contribution of Chinese or Indian astronomers to the understanding of the universe. Use your research to produce a poster or ICT presentation.

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Complete this digital doc: Worksheet 6.7: Astronomical history (doc-12392)

6.9 Review

6.9.1 Study checklist

Using technology to investigate the solar system

- **compare** the planets in the solar system 6.2
- **explain** why Pluto is no longer considered to be a planet 6.2
- **describe** examples of how technological advances have led to discoveries and increased our understanding of the solar system 6.2
- **identify** the forces keeping the planets in orbit 6.3
- **outline** features of the sun 6.3

Movements of the planets, moons and sun

- **explain** the importance of the sun in our solar system 6.3
- **distinguish** between comets, meteors and meteorites 6.4
- **outline** the ways in which the Earth moves 6.5
- **explain** night and day in terms of Earth's rotation 6.5
- **explain**, in terms of the tilt of Earth's axis and its revolution around the sun, what causes the seasons 6.6
- **describe** the surface of the moon 6.6
- **identify** the phases of the moon and **explain** how they occur 6.6
- **account** for the ocean tides in terms of the effects of the sun and the moon 6.6
- **describe** the appearance of the sun during a solar eclipse and the appearance of the moon during a lunar eclipse 6.7
- **explain** how solar and lunar eclipses occur 6.7

The development of our understanding of the solar system over time

- **describe** ideas developed by different cultures to explain astronomical observations **6.8**
- **describe** some of the models and theories of the universe that have been considered since the time of the ancient Greeks and then modified or rejected as a result of available evidence **6.8**

Individual pathways

ACTIVITY 6.1
Reviewing the solar system
doc-10549

ACTIVITY 6.2
Investigating the solar system
doc-10550

ACTIVITY 6.3
Investigating the solar system further
doc-10551

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FOCUS ACTIVITY

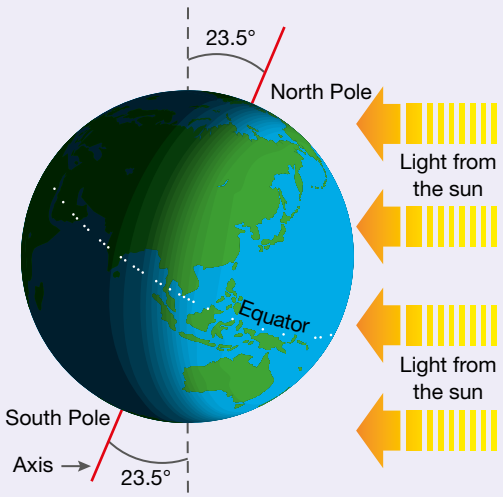
Create a multimedia presentation to **explain** how advances in technology have enhanced our understanding of the solar system. Do these discoveries **justify** the billions of dollars spent on the space program?

Access more details about focus activities for this topic in the Resources tab (doc-10548).

6.10 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.

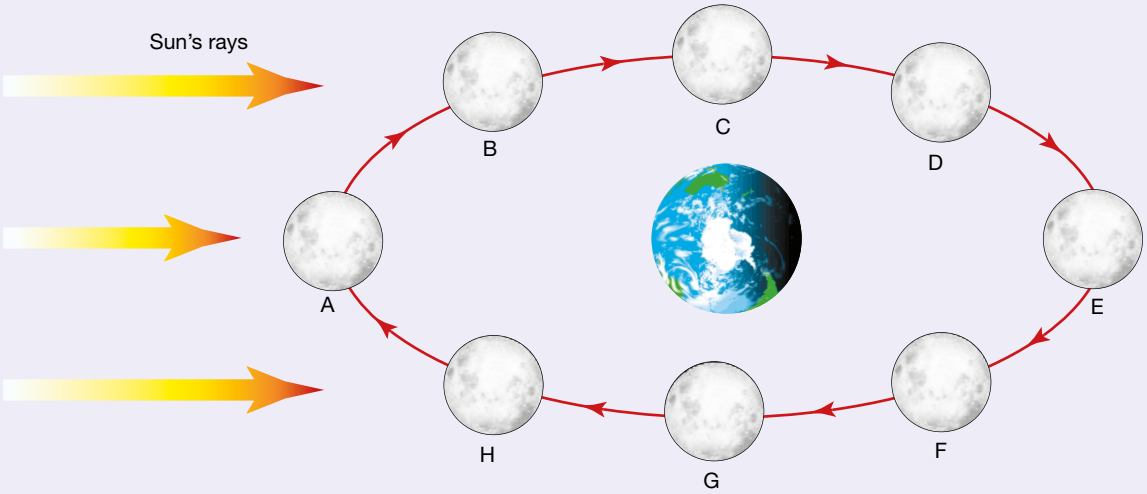
1. **Explain** why a day on Jupiter can be about 10 hours long.
2. **Explain** why our knowledge of the planets has increased so rapidly over the past 30 years.
3. The atmosphere of Mercury is very thin. **Describe** the effect this would have on the temperature on the planet.
4. The diagram below shows half of the Earth in sunlight while the other half is in darkness. Which Australian season is represented in the diagram. **Explain** how you know.



5. How many times does the moon rotate around its own axis while completing a single orbit of the Earth?
6. **Calculate** how many rotations the Earth has completed since you were born.

7. The diagram below shows the moon in eight different positions during an orbit around the Earth.
   (a) Copy the diagram and shade the parts of the Earth and moon that are in darkness.
   (b) How long does it take the moon to complete a single orbit?
   (c) Why is it not possible to see a new moon during the day?
   (d) Which position(s) of the moon would result in a quarter moon?
   (e) Which position(s) of the moon would result in a full moon?

The moon's orbit around the Earth as seen from above Antarctica



8. The photograph below shows the Earth as it is seen from the moon.

Photographs like this one of the Earth were taken from the *Apollo 8* spacecraft in 1968 as it orbited the moon.

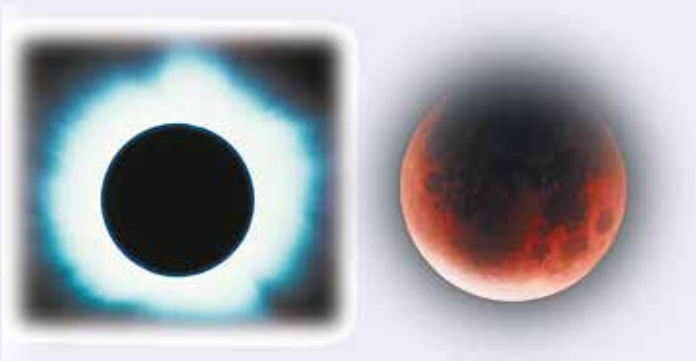


   (a) Why is the Earth visible even though it does not emit its own light?
   (b) Would you expect the Earth to always be visible from the part of the moon that faces it? **Explain** your answer.
9. The stars appear to change their positions during each night and during each year. **Explain** why the stars appear to move in circular arcs during the night.
10. **Distinguish** between a neap tide and a spring tide.
11. The table at right shows the high and low tide heights at Bondi beach over a 24-hour period of time.
    (a) **Calculate** how many hours pass between two consecutive high tides.
    (b) **Calculate** how many hours pass between two consecutive low tides.

Time	Height (m)
2.30 am	0.37
9.05 am	2.05
3.52 pm	0.1
9.53 pm	1.37

(c) **Explain** how high tides occur.
(d) **Deduce** why one high tide is lower than the other.

12. (a) **Identify** which of these photographs shows an eclipse of the sun and which shows an eclipse of the moon.

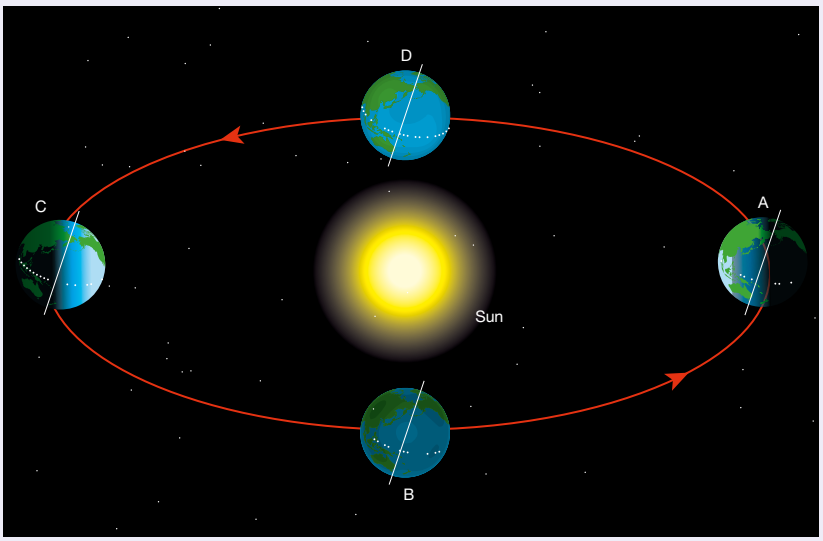


(b) Use labelled diagrams to **explain** how each eclipse occurs.

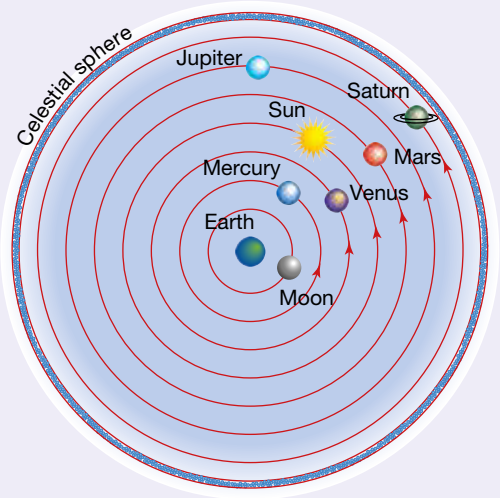
13. In searching for signs of life, either past or present, on other planets, what evidence would scientists be looking for?

Test yourself

1. The length of a day on the planet Venus is 243 Earth days. The length of a year on Venus is only 225 Earth days. This means that
   (A) it takes 243 days for Venus to orbit the sun.
   (B) Venus completes a rotation in 243 Earth days.
   (C) Venus completes a rotation in 225 Earth days.
   (D) it takes 225 days for the sun to orbit Venus. **(1 mark)**
2. During a solar eclipse:
   (A) the moon is blocked out by the sun.
   (B) the sun is blocked out by the Earth.
   (C) the moon is blocked out by the Earth.
   (D) the sun is blocked out by the moon. **(1 mark)**
3. The diagram below shows the Earth orbiting the sun.
   At what positions does Australia experience summer and winter respectively?
   (A) A and C
   (B) C and A
   (C) B and D
   (D) D and B **(1 mark)**



4. Shooting stars are
   (A) meteors.
   (B) comets.
   (C) supernova stars.
   (D) stars. **(1 mark)**
5. (a) Which astronomer developed the model of the universe shown in the diagram below? **(1 mark)**



   (b) **Identify** where the stars are in this model. **(1 mark)**
   (c) **Explain** why this model of the universe was so well accepted for almost 1500 years. **(4 marks)**

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Complete this digital doc: Worksheet 6.8: Solar system puzzle (doc-12393)

Complete this digital doc: Worksheet 6.9: Solar system summary (doc-12394)

TOPIC 7
Forces in action

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.

7.1.1 Why learn this?

In 2012, Felix Baumgartner, a former military parachutist from Austria, broke the record for the highest ever free fall from an altitude of 39 km. He plummeted from a balloon-borne capsule for five and a half minutes, reaching a top speed of over 1000 km/h before releasing his parachute, bringing him safely back to the ground. What force caused Baumgartner to reach such an incredible speed as he fell to Earth? How did his parachute slow his rate of descent so he could land safely?

LEARNING SEQUENCE

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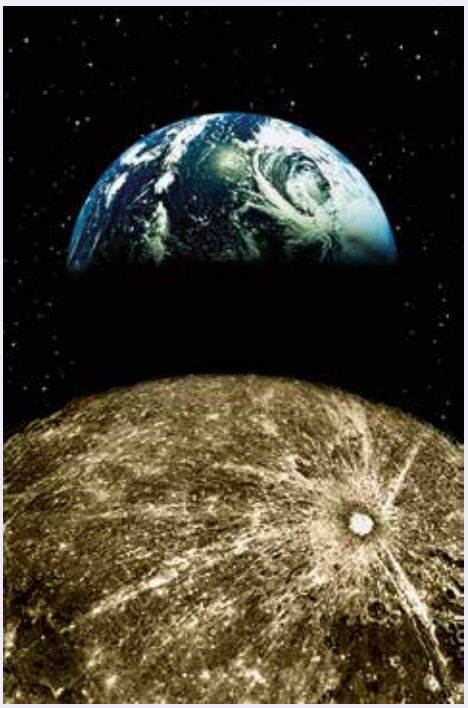
Parachutist Felix Baumgartner jumped from the edge of space to become the first man to break the sound barrier.



Thinking about forces

1. Work in small groups of three to four students and try the following activity.
   (a) Using a large piece of butcher's paper, draw up a table with terms listed in the left column of the table below.
   (b) Discuss each term and what you all think it might mean.
   (c) In column two of your table, write the possible meaning that your group proposes for each term. If your group finds a term difficult, you can write 'don't know', but don't be afraid to have an educated guess.
   (d) Share your group's responses with the class.

Term	Possible meaning
Force	
Friction	
Magnet	
Magnetic field	
Mass	
Gravity	
Weight	
Lubricant	
Buoyancy	
Surface tension	
Aerodynamic	



2. Identify the forces acting as you stretch a rubber band.
3. Why are bicycle helmets necessary?
4. Explain how a seatbelt protects you in a car crash.
5. Is there gravity on the moon? If so, is it the same as the gravity on Earth?
6. Is it easier to slide a heavy box over concrete or vinyl? Explain why.
7. Why are modern cars designed to be sleek and streamlined?
8. Give some examples of magnets used in household devices.
9. Are all metals magnetic? Elaborate.
10. Explain how heavy cargo ships can float on water.



7.2 What are forces?

7.2.1 Forces

A **force** is a push, a pull or a twist. A force can change the speed, direction or shape of an object. For example, when a racquet strikes a tennis ball, it can cause the ball to change speed and direction. It can temporarily change the shape of the ball too.

INVESTIGATION 7.1

What can a force do?

AIM: To observe changes that take place when particular forces are acting

You will need:

rubber band *nylon or wool cloth*
coin *tennis ball*
plasticine *plastic ruler or rod*

- Copy the following table into your notebook and write down your observations.
- Take notice of any changes in the motion or shape of each object and what caused the change in the motion or shape.

What to do	Observations	
	Changes in motion or shape	What caused the change
Stretch a rubber band.		
Squash a lump of plasticine.		
Push down on the floor with one foot.		
Drop a tennis ball. Observe what happens: (a) at the moment that you drop it (b) as it falls (c) as it hits the ground (d) as it goes up again.		
Flick a coin with one finger so that it slides along the floor or a table. Observe what happens after the coin is flicked.		
Charge a plastic ruler or rod by rubbing it with a nylon or wool cloth. Then hold it close to a thin stream of tap water.		

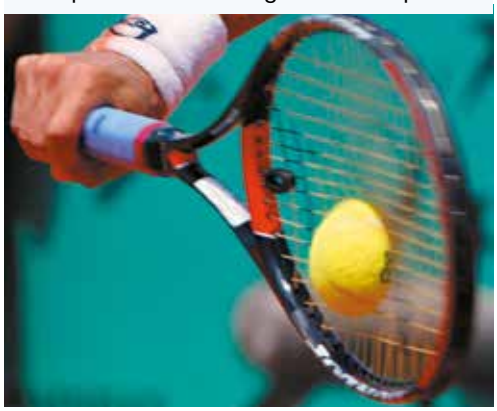
Discussion

1. When you squash a lump of plasticine or stretch a rubber band, a change in shape is observed. Explain what is different about the behaviour of these two materials after you have applied a force.
2. Does the tennis ball change its shape at all when it hits the ground? What would happen to a falling lump of plasticine when it hits the ground? Would it bounce? Check your prediction.
3. In which two experiments were you able to change the motion of objects without making contact with them?

7.2.2 Types of forces

Forces are acting around you all the time and they can cause changes to occur. Sometimes the effects are obvious and sometimes they are not. At this moment, forces are acting inside your body to pump blood around. When you write, you use a force to push the pen or pencil. The many examples of forces that affect our daily lives can be classified as either a **contact force** or a **non-contact force**.

A force can change the speed, direction or shape of an object. In this high-speed image, the force of impact between the racquet and ball changes their shapes.



Contact forces

Often, forces can act between two objects that are in contact with one another. Familiar examples of contact force include the force of your hand pulling your shoelaces, the force of your hand on a bottle top as you unscrew it, and the force of your schoolbag pulling down on your shoulders.

Other examples of contact forces include **friction** and **buoyancy**.

Friction is a contact force between two surfaces that are sliding, or attempting to slide, over one another. For example, there is friction between the tyres of your bike and the ground when you pedal. Without friction, the tyre would just slip and you would not move forward.

You cannot walk on water, but water does provide an upward force on you when you swim in it. This upward force is called buoyancy and it is the force that enables you, and ships, to float.

Non-contact forces

Forces can occur even between two objects that are not touching each other. These forces are called non-contact forces. Like all other forces, non-contact forces can affect the motion of an object — they can get the object moving, slow it down or stop it altogether.

Gravity is a non-contact force. We can see the effects of the force of gravity pulling on an apple from the Earth when the apple drops from a tree. The force of gravity acting on us is often called our weight. Gravitational forces also hold the moon in orbit around the Earth, and the planets in our solar system in orbit around the sun.

Magnetic forces can act without contact too. These forces act between two or more magnets, or between magnets and some metals, such as iron. **Magnets** have two ends or **poles**. When two magnets are brought together, they either **attract** (pull) or **repel** (push) each other, depending on the positions of the poles of the magnets.

Electrostatic forces sometimes cause your hair to stand on end immediately after you pull off a sweater. If you rub the end of your pen or ruler through your hair, you might even be able to pick up some small pieces of paper using this electrostatic force.

Forces can act between two objects that are in contact with each other.



You may experience an electrostatic force when you jump on a trampoline

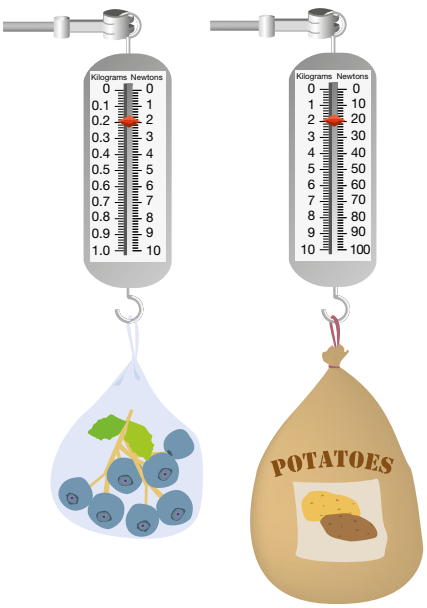


7.2.3 Measuring forces

The standard unit for force is the **newton (N)**, which is named after Sir Isaac Newton (1643–1727), an English physicist famous for his discoveries about how forces affect motion. He was also the author of many scientific laws about light and astronomy.

A **spring balance** is a device used to measure forces. An internal spring stretches as a force is applied to the spring balance, and we can read the force (in newtons) on the scale provided. Spring balances that contain stronger springs can measure larger forces. More sensitive spring balances have weaker springs and measure smaller forces.

Spring balances are used to measure forces.



7.2.4 Representing forces

Scientists use arrows in diagrams to represent forces. The direction of the arrow shows which way the force is acting. The length of the arrow shows how big the force is. A long arrow represents a larger, stronger force than a short arrow.

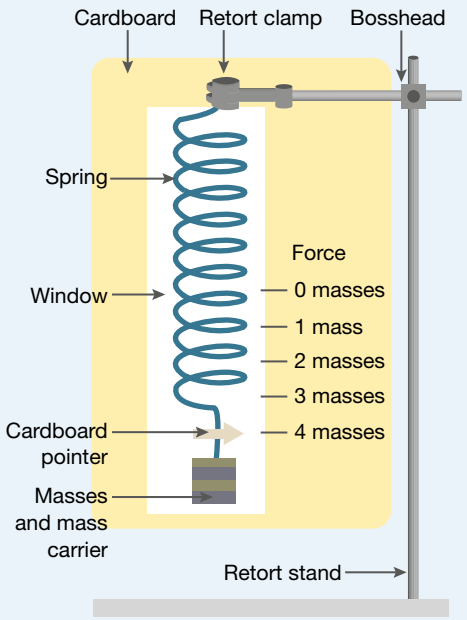
INVESTIGATION 7.2

The spring balance

AIM: To build your own spring balance

You will need:

cardboard
scissors
short coil or spring
mass carrier and masses
retort stand
Blu-Tack
retort clamp
bosshead



- Working in small teams, cut a window out of your piece of cardboard to match the dimensions of your fully stretched spring.
- Attach your spring firmly to the top of the window using Blu-Tack.
- Cut out a small arrow from the remaining cardboard to act as a marker for your spring and attach it to the top of the mass carrier using Blu-Tack.
- Commence creating the scale for your spring balance by marking the starting position on your window. Mark it as 0 masses.
- Suspend the mass carrier on your spring and then mark the new position as 1 mass.
- Add a mass to the carrier and mark it as 2 masses.
- Continue till the spring is fully stretched or you have run out of masses.

Discussion

1. Explain how a spring balance works.
2. Outline any problems you encountered.
3. Why was it useful to work in teams in this investigation?

The arrows that represent forces acting on an object should be drawn from the object's **centre of gravity**. All objects, including your body, have a centre of gravity. Picture a point in your body where your weight would be concentrated if your body was a single point. That point is called your centre of gravity.

7.2.5 Balanced and unbalanced forces

Forces act on us all the time when we are moving and even when we are stopped. More than one force is acting on us all the time. The forces acting on us can be **balanced** or **unbalanced**.

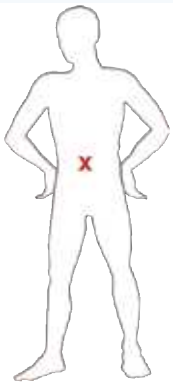
Balanced forces

The arrows describing the up and down forces acting on the kayaker are the same length. This shows that the forces are the same size. But these forces are acting in opposite directions. The force of gravity pulls down on the kayaker, but the buoyancy force of the water pushes up. The two forces are balanced so the kayaker does not move up or down.

Unbalanced forces

The arrows describing the forward and backward forces on the kayaker are not the same length. The forward force comes from the kayaker using a paddle to push forwards. The backward force is the **drag** from the water slowing the kayak down. These forces are unbalanced. Unbalanced forces cause objects to speed up, slow down or change direction. The forward force is larger than the backward force, so the kayaker and his kayak move forwards faster and faster. Eventually they cannot move any faster because drag increases when speed increases.

Your centre of gravity changes with your position. When standing, your centre of gravity is at about belly-button height.







The effect of balanced and unbalanced forces

Unbalanced forces cause things to start moving, like a kayak in the water. Unbalanced forces can increase or decrease the speed of the kayak as well. If the forward and backward forces are balanced, there is no increase or decrease in speed; the kayak moves at a steady speed or remains stationary.

These forces are unbalanced. Why? Which way is the seesaw moving?



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. **Define** the term 'force'.
2. **Identify** the three possible results of a force acting on an object.
3. Which of the following forces are non-contact forces? friction, electrostatic force, magnetic force, gravity
4. **Outline** how the size of a force is represented in a diagram.
5. **Explain** why a spring balance can be used to measure force.
6. **Identify** the force that slows down movement through water.

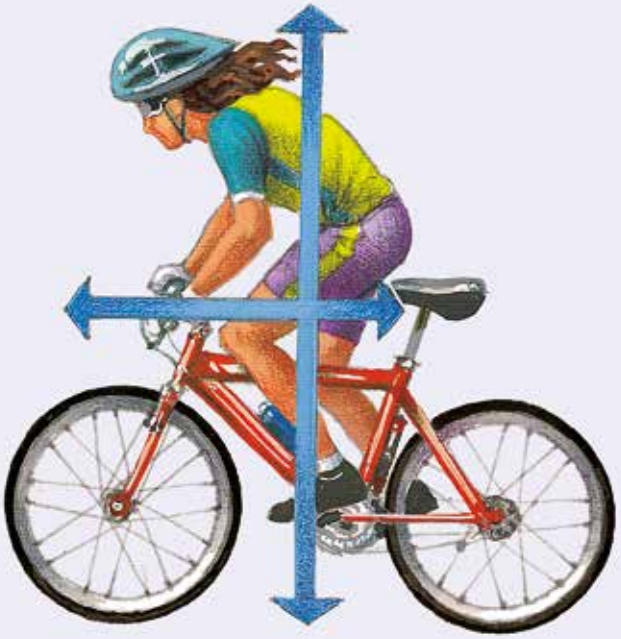
Think

7. Copy the following table into your workbook. Complete it by thinking of one or two everyday examples of forces that produce the effect in the first column. You can complete your table with diagrams or words.

Everyday effects of forces

Effect	Examples of forces in everyday life
Starting motion	
Stopping motion	
Speeding up motion	
Slowing down motion	
Changing the direction of motion	
Changing the shape of an object	
Having no visible effect	

8. When you flick a coin so that it slides across a table, it slows down.
   (a) **Identify** the force that slows the coin down.
   (b) While your finger is still pushing the coin, there are four forces acting on the coin. What are they? Draw a diagram with arrows showing the direction in which each of the four forces pushes or pulls.
   (c) How many forces are acting on the coin after your finger stops pushing?
9. Air resistance is the force that results as objects move through the air. Is air resistance a contact or a non-contact force? **Explain** your answer.
10. There are four forces acting on the person in the diagram at right.
    (a) **Identify** which forces are balanced.
    (b) **Identify** which forces are unbalanced.
    (c) Is the rider's speed increasing, decreasing or constant?
11. Redraw the force arrows in question 10 to show the forces acting when the bike rider is slowing down.
12. Choose two objects around you. Use arrows to draw the forces you think are acting on the objects. (*Hint:* You can tell if forces are balanced or unbalanced by looking at the object's motion.)



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Watch this eLesson: Isaac Newton (eles-1771)

Complete this digital doc: Worksheet 7.1: Types of forces (doc-12395)

Complete this digital doc: Worksheet 7.2: Measuring forces (doc-12396)

7.3 Friction

7.3.1 Friction

Have you ever tried to walk across ice? It's difficult to start moving because you can't easily push off from the slippery surface. Once you're moving, it's then hard to stop. Walking along a concrete path is much easier. The rough concrete provides far more friction than slippery ice, allowing a better grip.

Friction is a force that opposes the movement of an object. It occurs between any surfaces that are in contact and sliding past each other. Objects travelling through air or water also experience friction.

Friction forces are particularly high if the surfaces in contact are rough. Small bumps on the surface of a rough object catch on bumps on the surface of the other object and slow down the movement.

Friction can act between any two materials in contact with each other. These two materials might be solids, as in the case of a car tyre and the road. Fluid friction, sometimes called drag, involves contact with a fluid or the air. Examples include the air drag on a fast-moving car or the fluid friction on a motor boat travelling through water.

The friction between two surfaces, such as when you rub your hands together or sharpen a pencil, creates heat.

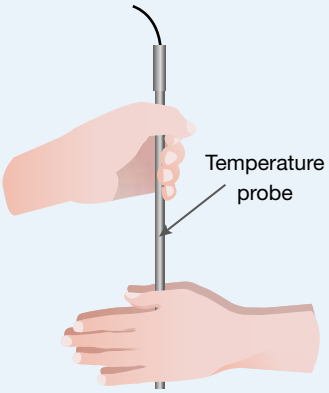
INVESTIGATION 7.3

The heat from friction

AIM: To observe the heat generated from the friction between two surfaces

You will need:
data logger and temperature probe

- Work in groups of two or three.
- Connect the temperature probe to the data logger.
- Set the logger time to 15 seconds and the timing rate to 0.1 seconds (10 samples/second).
- One student places the tip of the temperature probe in the centre of the two hands of another student who will be rubbing them together.
- Start logging the temperature as the second student commences rubbing their hands together at a constant rate for at least 15 seconds.
- Record your results in your notebook. You can either download and print the data table and line graph from the data logger or create a table yourself to record the temperature each second and plot your data as a line graph with a smooth curve of best fit.



Discussion

1. What evidence is there that friction generates heat?
2. Did the amount of heat created increase the longer that the friction force acted? Refer to your graph when answering this question.
3. Why might you see someone rubbing their hands together on a cold winter's day?

7.3.2 Using friction

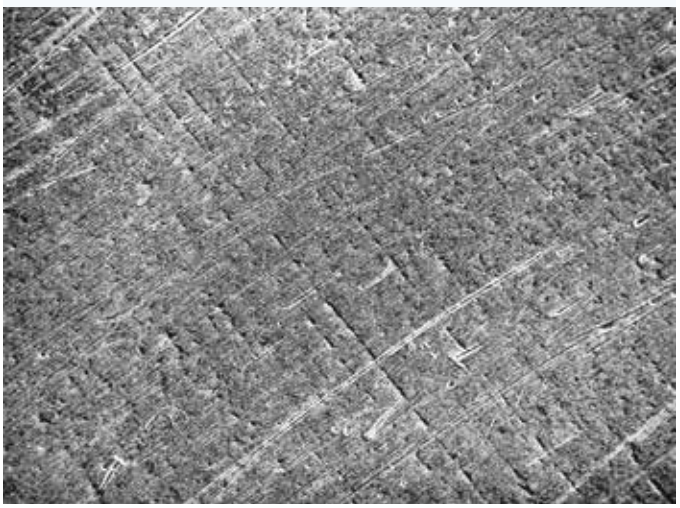
At times, friction can be a nuisance. For example:

- Try sliding a heavy object across a rough surface. Before an object will move, you need to push or pull it with a force greater than the friction force.
- Swimmers have to work hard to overcome the drag of the water. In other sports, like motor racing, cars need to be specially designed to keep drag from the air as small as possible.
- When engine parts rub together, they can cause the engine to overheat.

At other times, we need friction. For example:

- The friction between our feet and the ground means that we can push off and start walking. It also means we can stop without sliding.
- On a flat road, the friction between a tyre and the road is needed to start the car moving. Without it, the tyres would spin on the spot and the car wouldn't move. Tyres are designed with tread patterns that optimise friction on the road.
- Rubbing your hands together on a cold day helps to keep you warm. Whenever friction occurs, the temperature of the two interacting surfaces increases.

A scanning electron microscope image of the surface of polished stainless steel. Even surfaces that seem smooth still have small bumps in them. The bumps on a surface get caught on, or grip, the bumps on another surface that is rubbing against it. That's why friction is often called grip.



7.3.3 What affects friction?

The size of a friction force depends on the objects that are rubbing against each other. Friction is usually greatest between two rough surfaces. It also increases when the objects are pressed together tightly.

This box is easy to slide across the floor. Only a small force is needed to overcome the friction between the box and the floor.



This box is much harder to push. A big force is needed to overcome the friction between the heavy box and the floor. The friction has increased because the bumps along the surfaces of the box and the floor are pressed together more tightly.



INVESTIGATION 7.4

Measuring friction

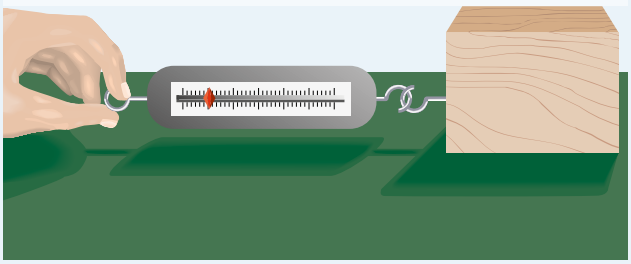
AIM: To compare the friction between different objects

You will need:

block of wood with hook attached
several identical blocks of wood
spring balance

- Copy the table below into your notebook.
- Use a spring balance to pull a block of wood across your desktop. As long as you pull steadily, the reading on the spring balance will be equal to the force of friction on the moving block.
- Record your reading in the table.

Use a spring balance to pull a block of wood across a surface.



Friction on different surfaces

	Force of friction (newtons)			
	Trial			
Surface	1	2	3	Average

- Repeat your measurement two more times on the desktop and calculate the average force of friction. Record all data in the table.
- Repeat this procedure on several other surfaces of your choice. Surfaces that you might test are vinyl floor, carpet, doormat, concrete and bitumen.
- Summarise your average results in a bar or column graph.
- Design and carry out an experiment to investigate the effect of mass on the size of the friction force. Record your results in a table and display them on a line graph.

Discussion

1. List the surfaces in order, from greatest friction force to least.
2. What feature of a surface seems to determine the amount of friction?
3. For this investigation, identify:
   (a) the independent variable
   (b) the dependent variable
   (c) two important control variables.
4. Why was it a good idea to repeat each measurement three times?
5. Do heavier objects experience more friction?

7.3.4 Friction at work

Friction might seem like the last thing you would want if you were in a bike race. Many bikes have a **streamlined** design to reduce the **air resistance** acting on the bike and the rider. But, if you were in a downhill mountain-bike race, you might want to reconsider. **Traction** in this sport is very important.

Friction allows objects in contact with the ground to have good traction. Traction describes how an object 'sticks' to another. Tyres with good traction grip the road and turn without sliding or spinning on the spot.

Downhill mountain-bike riding requires good traction. The downhill surface is steep, bumpy and has many loose particles that slide over the ground surface easily. Without good traction, downhill mountain bikes could slide out of control, all the way down a mountain. Traction helps to keep the tyres in contact with the surface and gives the rider control.

It also means that the bike can slow down or stop if the rider needs to do so.

Traction is also important when walking. To walk forwards, your foot needs to push back on the ground. If you have good soles on your shoes and a rough surface to walk across, you can move forwards.

When walking across a slippery surface, such as ice, it is possible for your foot to slip backwards because there is less traction.

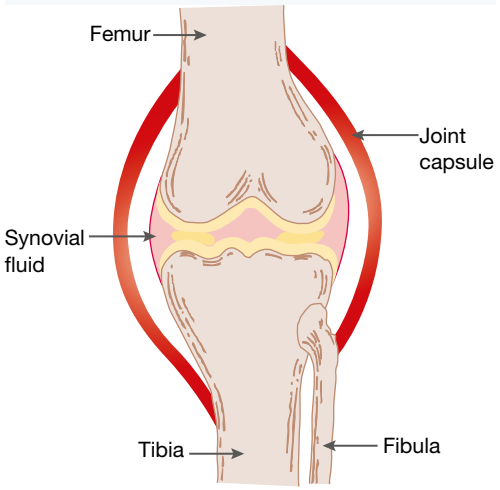
Downhill mountain bikers stay in control with the help of bike tyres that are designed to provide good traction on dirt tracks.



Friction between moving parts causes them to heat up; this is not good for a machine with moving parts, but great if you are cold. Campers in the cold rub their hands together to warm them.

Your joints contain a lubricant called synovial fluid to help stop bones from scraping against each other.

Synovial fluid lubricates joints, like this one in the knee, and so reduces friction.



INVESTIGATION 7.5

Shoes and friction

AIM: To compare the friction of a variety of shoes

Design an experiment to compare the friction of a variety of shoes with a particular floor surface.

- Collect a variety of shoes to test. Include different brands of school shoes and runners.
- Identify the equipment you will need to measure the friction that exists between each shoe and a particular floor surface.
- Collect information about each shoe to be tested, such as length, mass, sole material and tread.
- Write up the method used in your investigation using a scientific report format.
- Record your results in a suitable table.

Discussion

1. Write a suitable conclusion to your experiment.
2. Identify the variables that you controlled and the variables that you would have liked to control but could not.

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. **Define** the term 'friction'.
2. **Explain** why friction is important when you walk.
3. **Identify** the name of the friction force that acts on an object moving through the air.
4. Apart from the roughness of the surfaces rubbing together, **identify** one other variable that increases the size of a friction force.

Think

5. For each of the 'friendly friction' sketches below, state:
   (i) how the friction force is being helpful
   (ii) what would happen if the friction force was absent.

Friendly friction

(a) 

(b) 

(c) 

6. For each of the 'unfriendly friction' sketches below, state:
   (i) how the friction force is being a nuisance
   (ii) what could be done to reduce the effect of the force of friction
   (iii) what could be done to reduce the force of friction.

Unfriendly friction

(a) 

(b) 

(c) 

7. In *Investigation 7.4*, (page 249) the block needed to be pulled at constant speed.
   (a) Draw a diagram of the block and the surface it is moving along. Add arrows to represent the forward and backward forces.
   (b) What size must the arrows be, compared with each other, if the block is speeding up?
8. Motorists are advised that they will waste fuel if their tyres are under-inflated. **Explain** why this is so.
9. The force stopping a mountain bike from sliding out of control down a hill is traction. **Identify** the force that pulls the rider and the bike down the mountain.

Create

10. Imagine a world without friction. Write a story about how your life would be different without friction. What things would be easier to do? What things would become almost impossible?
11. Using the **Friction as a driving force** interactivity in the Resources tab, match different car tyres to the right weather conditions. Run simulations to see if you can achieve the perfect amount of friction.

learnon RESOURCES — ONLINE ONLY

Watch this eLesson: Friction as a driving force (eles-0032)

Try out this interactivity: Friction as a driving force (int-0054)

Complete this digital doc: Worksheet 7.3: Friction (doc-12397)

7.4 Magnetic forces

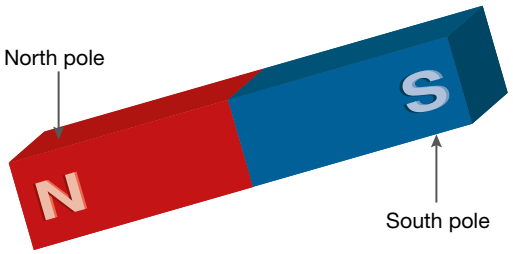
7.4.1 Magnets

Make a list of all the things that you come into contact with every day that use magnets. The pictures opposite will give you some clues. You might like to share your ideas with others and compile a class list.

Almost every time you push or pull an object, you have to touch it. Magnets can pull objects without actually touching them; the force between a magnet and an attracted object is an example of a non-contact force. The closer the magnet is to the object, the greater the size of the pulling force.

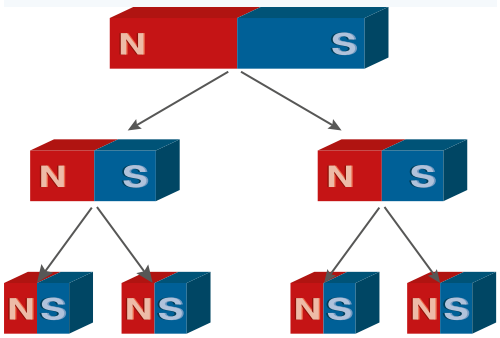
7.4.2 Poles

The pulling force of a magnet is strongest at its ends, or poles. All magnets have a north pole and a south pole.



Even when a magnet is cut in half, each half still has a north pole and a south pole. If you could keep cutting a magnet in half over and over again, each half would always have both a north pole and a south pole.

Magnets always have a north and south pole, even if broken in half.



Magnets that might be found at home



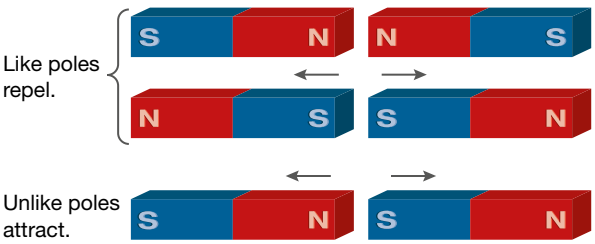




Opposites attract

When the north poles of two magnets are brought close together, the magnets push away (or repel) each other. This same **repulsion** force is felt between two south poles.

When the north pole of a magnet comes close to the south pole of another magnet, the opposite happens. They pull on each other, or attract one another.



7.4.3 Magnetic fields

The metallic objects attracted to a magnet lie within the magnet's **magnetic field**. The magnetic field is the area around a magnet where its magnetic force acts.

Although magnetic fields are invisible, we can visualise what they look like by sprinkling iron filings around a magnet. The iron filings line up along the magnetic field lines.

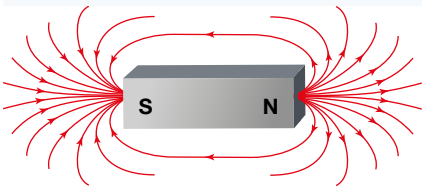
The magnetic field is drawn as shown below. The lines show the direction of the magnetic force. The lines are closest together where the magnetic force is greatest and are furthest apart where the magnetic force is weakest.

Just as iron filings align with the magnetic field, the needle of a compass lines up with the magnetic field. The north pole of the compass points in the direction of a magnet's magnetic field.

Iron filings sprinkled around bar magnets



The magnetic field around a bar magnet



INVESTIGATION 7.6

Magnetic materials

AIM: To investigate whether materials are attracted to magnets

You will need:

bar magnet
selection of materials to be tested (see the list below)

- Place a bar magnet close to a range of materials to find out which ones are attracted to it. Record your observations in a table like the one below.

Attracted	Not attracted

- Test as many of the following items as possible: pencil, paper, plastic straw, coins, iron nail, stainless steel spoon, aluminium foil, paperclip, copper wire.

Discussion

1. Which materials were attracted to the magnet?
2. Were all the metals attracted to magnets?
3. Of the materials that were attracted to the magnet, which one was attracted the most? Why do you think this was so?

INVESTIGATION 7.7

Poles apart

AIM: To investigate whether poles attract or repel

You will need:

2 bar magnets

- Take two bar magnets and identify the north and south pole of each. Position the magnets near each other as shown below. Record whether the magnets attract or repel each other in each case.

Attraction or repulsion?

(a)	N	S
(b)	N	N
(c)	S	S
(d)	S	N

Discussion

1. Complete the sentences to form your conclusion:
   Like poles _____.
   Unlike poles _____.

INVESTIGATION 7.8

The magnetic field

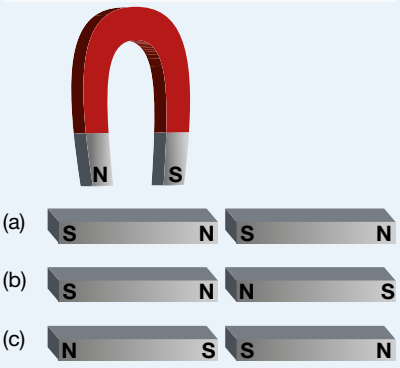
AIM: To map the magnetic field around magnets

You will need:

horseshoe magnet *iron filings*
overhead transparency *sheet of A4 paper*
2 bar magnets *small compass*

- Place a bar magnet in the centre of a sheet of white paper. Cover the paper and magnet with an overhead transparency.
- Carefully sprinkle iron filings over the transparency, gently tapping it to spread the filings out. Take care not to let iron filings get under the transparency.
- Draw a diagram of the pattern made by the iron filings. Label the north pole and south pole of your magnet on the diagram. The pattern in your diagram is a map of the magnetic field around the bar magnet.
- Use the iron filings to investigate the magnetic fields around a horseshoe magnet and the pairs of magnets shown at right.

Use the iron filings to investigate the magnetic fields around these magnets.



Discussion

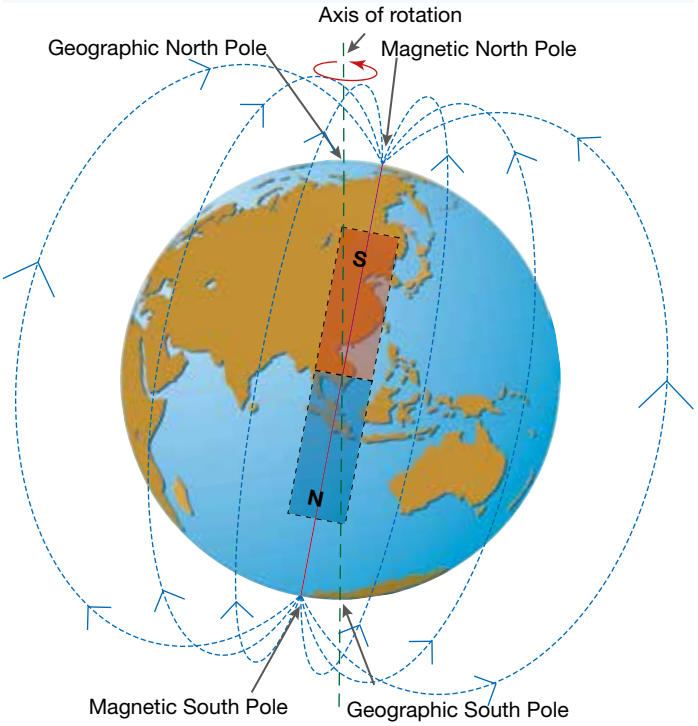
1. Where does the magnetic field appear to be strongest? How do you know this?
2. What happens to the strength of the magnetic field as you get further from the magnet?
3. Place a compass at several positions around the bar magnet. The direction in which the north-pointing needle of the compass points shows the direction of the magnetic field lines. Draw a diagram of the magnetic field around the bar magnets. Add arrows to your diagram to show the direction of the magnetic field.
4. Do the magnetic field lines run from north pole to south pole or from south pole to north pole around the magnet?

7.4.4 The Earth's magnetic field

If you hang a magnet from its middle, it always lines up with the North and South Poles of the Earth. The Earth, like the sun and some planets, has its own magnetic field. It is very much like the magnetic field of a bar magnet. Scientists have proposed a number of different theories to explain what causes the Earth's magnetic field. One popular theory is that, as the Earth spins, the movement of molten iron in the Earth's outer core creates electric currents in the core that generate the magnetic field.

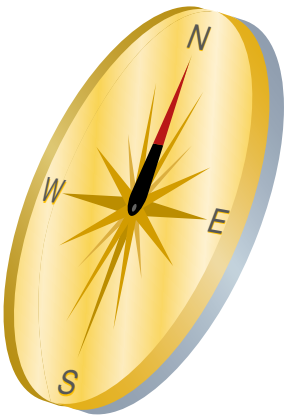
Notice that there are two north poles and two south poles marked on the diagram at right. The **magnetic North Pole** is located nearly 1000 km from the geographic North Pole. Similarly, the **magnetic South Pole** is found just over 1000 km from the geographic South Pole.

The Earth's magnetic field



Which way is north?

A compass is a simple tool for letting us know where north is. The compass needle moves freely around the centre point until it points north. It is pushed and pulled by magnetic forces so that it lines up with the Earth's magnetic field, just like a hanging magnet. In fact, a compass needle is a magnet.

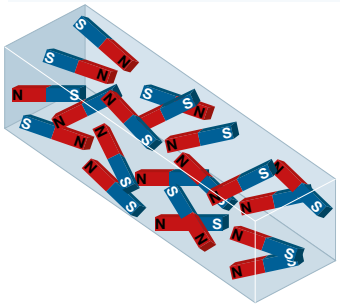


The tip of the needle that points or 'seeks' north must be the north pole of the magnet. The north pole of a compass actually gets its name from the term 'north-seeking pole' because it lines up or 'seeks' the magnetic North Pole of the Earth. For the north pole of a magnet to point to the Earth's North Pole, this pole of the Earth must really be acting like the south pole of a magnet — remember that opposites attract!

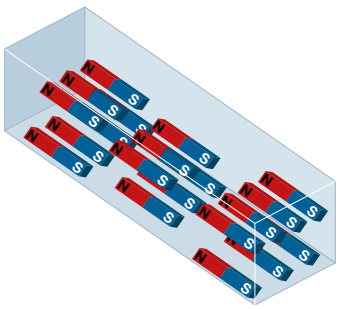
7.4.5 Three special metals

Not all objects are attracted to magnets. Magnets affect only materials containing the metals iron, nickel or cobalt. Steel is a metal **alloy** and is made of a mixture of metals. Whether steel is attracted to a magnet depends on the combination of metals in it. Scientists have developed a model or visual representation to explain what causes these metals to be magnetic. In their model, the metals are thought to be made up of small components called **domains**, which behave like mini-magnets. Each of these domains or mini-magnets has a north pole and a south pole.

If the domains inside magnetic materials are facing different directions, the pushes and pulls of the 'mini-magnets' are cancelled out. It results in the material not behaving like a magnet.



If the domains are lined up facing the same direction, the material has an overall north pole and an overall south pole. The material will behave like a magnet.



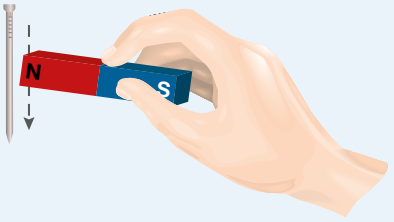
INVESTIGATION 7.9

Making your own compass

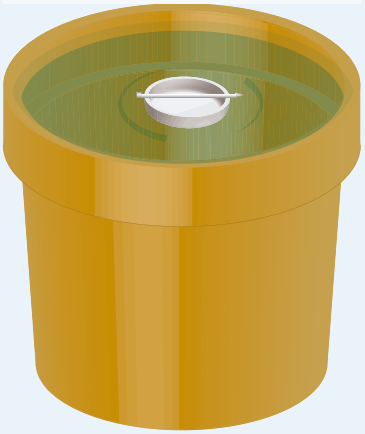
AIM: To make a compass

You will need:

large iron nail (about 50 mm long)
strong bar magnet
paperclips or small nails
container of water
styrofoam cup



Make your own compass.



- Take a large iron nail and stroke it with a strong permanent magnet. After each stroke, lift the magnet high above the nail before commencing the next one. You need to make sure that each stroke is in the same direction and made with the same end of the magnet.
- After a total of 40 strokes, test your new magnet by trying to attract paperclips or small nails.
- Compare the strength of your magnet with that of others in your class.
- Use your magnet to make a compass like the one shown opposite. You will need a container of water and a float. The bottom of a styrofoam cup will make a good float.
- Try dropping your 'homemade' magnet on the floor several times. Test it to see if it still works.

Discussion

1. Which end of your magnet is the north pole? How do you know?
2. Explain, in terms of domains:
   (a) how stroking a nail could make this nail act like a magnet
   (b) why dropping your nail magnet several times weakens its strength as a magnet.

As well as being affected by magnets, iron, nickel and cobalt can also be made into magnets. When the domains inside the metals face the same direction, the metal acts as a magnet.

A needle or nail can be magnetised by stroking it with a bar magnet in the same direction many times. The domains in the needle are lined up only temporarily and eventually they go back to their original directions. Such objects are called temporary magnets.

Bar and horseshoe magnets are permanent magnets. They do not lose their magnetism easily, except by being dropped or by being heated to very high temperatures.

7.4.6 Switched on magnets

A magnet's pulling force can be very useful, but sometimes it gets in the way. An **electromagnet** is a magnet that can be turned on and off with the flick of a switch. It is made up of a coil of wire wrapped around a piece of iron. The piece of iron turns into a magnet when electricity passes through the coil. The iron stops being magnetic as soon as the electricity is turned off.

Electromagnets are used in many machines and appliances. The photograph at right shows one such use. The electromagnet is attached to a giant crane. The electric current is turned off while the electromagnet is lowered into a position over the load of scrap metal to be lifted. When the current is switched on, the iron or steel in the scrap metal is attracted to the electromagnet and lifted

The electromagnet attached to the crane attracts iron and steel objects when the electric current is switched on.



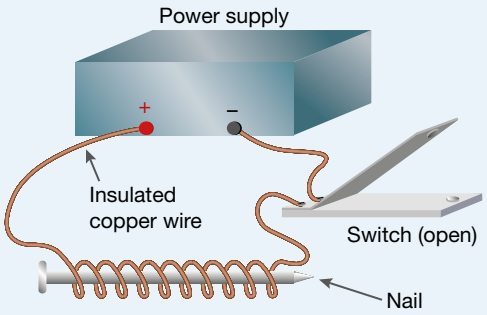
INVESTIGATION 7.10

Making electromagnets

AIM: To investigate what affects the strength of an electromagnet

You will need:

power supply
2 insulated wires, one short, the other 1.5 m long
large nail
switch
paperclips



- Set up the circuit shown at right.
- Wind the long wire neatly around the nail 15 times.
- Set the power supply to 2 volts and close the switch. Test the nail to see if it will pick up any paperclips.
- Record your results in a table like the one below.

Voltage of power supply (V)	Number of turns of wire	Number of paperclips picked up
2	15	
2	20	
2	25	
2	30	
4	15	
4	20	
4	25	
4	30	

- Wind five more turns of wire onto the nail.
- How many paperclips does the electromagnet pick up now?
- Keep winding the wire onto the nail. Record the number of paperclips picked up for 25 and 30 turns of wire.
- Raise the voltage to 4 volts. Repeat the previous steps.

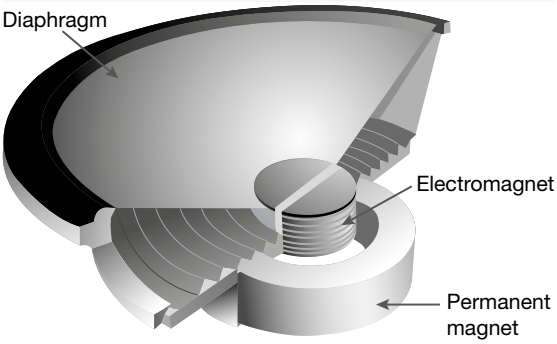
Discussion

1. What effect does increasing the number of turns of wire have? Refer to your results.
2. What effect does increasing the voltage supply have?
3. What factors affect the strength of your electromagnet?

into a container. When the electric current is switched off, the metal falls from the crane's electromagnet. However, if the metal was not mostly iron or steel, the electromagnet would be of little or no use.

Electromagnets like the one in the photograph are also useful in separating iron and steel from other scrap metal. The scrap metal is first shredded into small pieces.

Cross-section through a speaker



7.4.7 Using magnets

Permanent magnets and electromagnets are commonly used in our daily lives. The microphones and speakers in devices like telephones contain both permanent magnets and electromagnets. Doorbells and metal detectors also rely on electromagnets. High-speed trains in Europe and China use electromagnets to elevate the train to reduce friction.

The voice we hear through the telephone or the music that comes from our stereo or mp3 player is produced by a speaker. The sound is generated when electricity passes into a coil of wire causing it to become an electromagnet. The electric current in the electromagnet changes direction causing it to be attracted and repelled by a ring-shaped permanent magnet around it. This makes the diaphragm of the speaker vibrate, which produces the sound.

INVESTIGATION 7.11

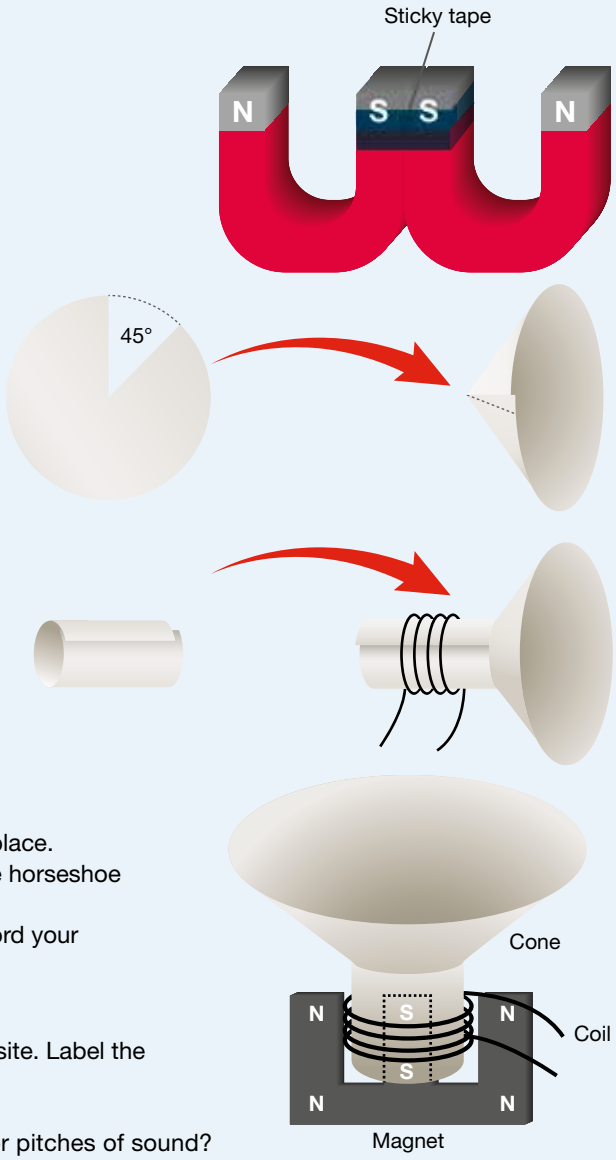
Build a loudspeaker

AIM: To model a loudspeaker

You will need:

AC power supply
1 metre of insulated copper wire
two wire leads with alligator clips
cardboard
two horseshoe magnets
sticky tape

- Tape together the like poles of two horseshoe magnets side by side so that they form a W shape.
- Cut out a circle of cardboard. Cut a wedge out of the circle and bring the cut edges together to make a shallow cone. Tape the edges together so that the cone will keep its shape.
- Cut a strip of the cardboard approximately 5 cm by 20 cm. Roll the strip up to make a tube about 3 cm diameter, or just large enough to slip over the two taped poles of the horseshoe magnets. Tape the cardboard tube so that it keeps its shape.
- Place the tube on the point of the cone and fix it there with several strips of tape.
- Wind the copper wire around the tube and tape it in place.
- Position the loudspeaker over the central poles of the horseshoe magnet.
- Connect the coil to a low-voltage AC supply and record your observations.



Discussion

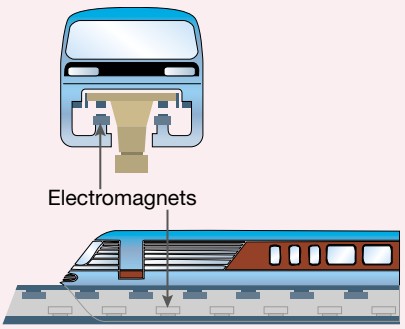
1. Copy the illustration of the model loudspeaker opposite. Label the permanent magnet and the electromagnet.
2. Explain why the cone moves.
3. How might a loudspeaker produce different tones or pitches of sound?

HOW ABOUT THAT!

The maglev train gets its name from MAGnetic LEVitation. It reaches speeds of up to 500 km/h and doesn't even need a normal engine to run! It uses pushing forces between electromagnets, both on the track and on the train, to keep them apart.

Electromagnets also propel the train forwards. Magnets ahead of the train pull the train forwards. Magnets behind the train push it forwards.

The maglev train seems to float above the train tracks. Eliminating friction allows the train to travel at very high speeds.



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. **Identify** which of the following statements is correct.
   (a) Permanent magnets never lose their magnetism.
   (b) All metals are strongly attracted to magnets.
   (c) All permanent magnets have a north pole and a south pole.
   (d) Iron is the only material attracted to magnets.
2. If you broke a bar magnet in half, would one half be a north pole and the other half a south pole? **Explain**.
3. How should two bar magnets be placed on a table so that they repel each other?
4. **Define** the term 'magnetic field'.
5. How can you tell where the magnetic field is strongest around a magnet?
6. **Outline** how the direction of a magnetic field is determined.
7. **Explain** why hanging magnets line up with the North and South Poles of the Earth.
8. **Describe** what an electromagnet is and **explain** how it works.
9. List some everyday devices that use electromagnets.

Think

10. Make a list of as many items as you can that are, or contain, permanent magnets.
11. The magnetic North Pole of the Earth can be considered as one pole of a bar magnet. Is it acting as the south pole or the north pole of a magnet? **Explain** your answer.
12. Which way would the north-seeking end of a compass point if you were in a plane flying directly above the Earth's magnetic North Pole?
13. State the advantage of an electromagnet over a permanent magnet.
14. **Explain** why a maglev train is able to travel so fast.

Investigate

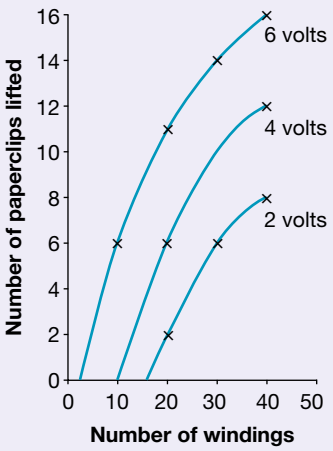
15. Design and carry out an experiment to measure the strength of different magnets. Record your measurements in a table and display them using a column graph.

Design and Create

16. Design a poster to illustrate the variety of common devices that use permanent magnets and electromagnets.
17. **Construct** a device that uses an electromagnet to make a noise when you close a switch or push a button.

Analyse

18. Arianna made her own electromagnet to find out how the number of windings around a nail affected the number of paperclips that the nail could pick up. She used the circuit shown in *Investigation 7.10* with the power supply set to 2 volts. Arianna then repeated her measurements with the power supply set to 4 volts and then to 6 volts. She recorded her observations in a table and then constructed the graph at right.
    (a) How many paperclips did Arianna lift with 20 windings and the power supply set to 6 volts?
    (b) Arianna lifted 12 paperclips when the power supply was set to 4 volts. How many windings were there around the nail?
    (c) How many paperclips could Arianna expect to lift with 50 windings around the nail and the power supply set to 2 volts?
    (d) Suggest a way that Arianna would be able to improve the reliability of her results.



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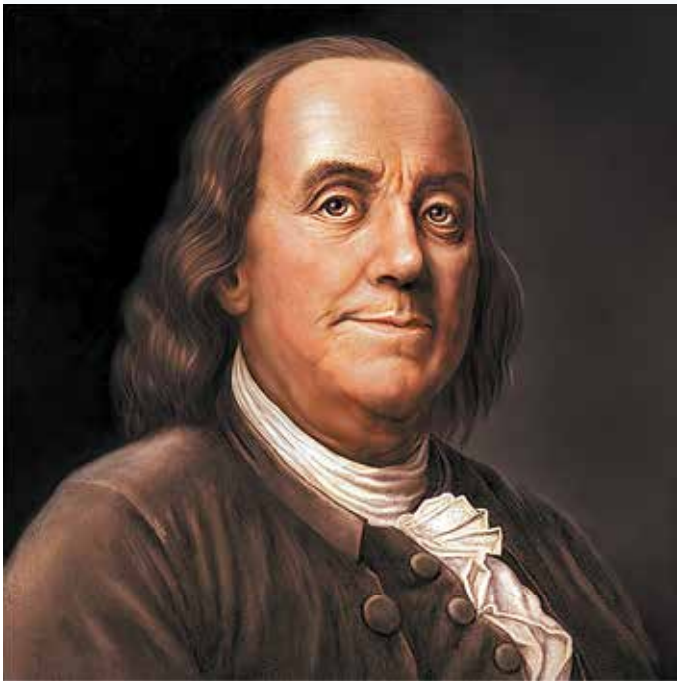
Complete this digital doc: Worksheet 7.4: Magnetic forces (doc-12398)

Complete this digital doc: Worksheet 7.5: Electromagnetism (doc-12399)

7.5 Electrostatic forces

7.5.1 Inside atoms

Benjamin Franklin discovered the electrical nature of lightning.



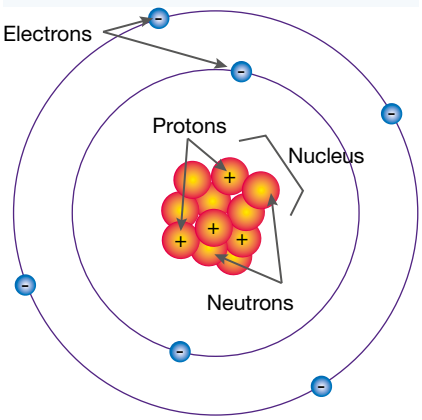
You may have experienced static electricity when you removed a jumper or blouse. It sometimes creates forces that cause your hair to stand up on end or creates little sparks that tingle. To explain the nature of static electricity, it is important to have an understanding of the **atom** and the subatomic particles that make them up.

The idea that all matter is made up of atoms originated in ancient Greek times around 2500 years ago. Experiments done in the 1800s and 1900s provided evidence for the existence of subatomic particles that today we call electrons, protons and neutrons.

Scientists' understanding of the structure of atoms has helped them to explain how objects can acquire an electric **charge**. Benjamin Franklin, an American scientist in the 1700s, was the first person to use the term 'charge'. He also named the two charges positive and negative. Like the poles of a magnet, they are opposite to one another.

7.5.2 Positive or negative?

A neutral atom contains an equal number of protons and electrons. (Some of the protons are hidden in this diagram.) This diagram represents a carbon atom. The number of neutrons is not always the same as the number of protons.



At the centre of each atom is a heavy **nucleus**. Surrounding the nucleus is a lot of empty space and tiny particles called **electrons**. Electrons are constantly moving around the nucleus. Each electron carries a **negative electric charge**.

Inside the nucleus are two different types of particles. The **protons** inside the nucleus are much heavier than electrons. Each proton carries a **positive electric charge**. The **neutrons** inside the nucleus are similar to protons but carry no electric charge. The positive electric charge of a proton exactly balances the negative charge of an electron. Atoms usually contain an equal number of electrons and protons.

Any material that has more protons than electrons is said to be **positively charged**.

Any material that has more electrons than protons is said to be **negatively charged**.

Any material that has equal numbers of electrons and protons is said to be neutral. The term 'uncharged' is also used to describe neutral materials.

HOW ABOUT THAT!

The central part of the atom is called the nucleus. The nucleus is very small compared with the overall size of the atom. To give you an idea of the size of the nucleus compared with the whole atom, imagine this: If an atom was as big as the Sydney Cricket Ground, the nucleus would be the size of a marble placed at its centre.



7.5.3 Getting charged

Objects usually become charged by the addition or removal of electrons. This charge is called an **electrostatic charge** because, once an object gains an electric charge, it remains 'static' or stationary on that object. Only in conductors (mainly metals) do charges move through the object, creating a 'current' of charge rather than a static charge.

There are two ways that an object can gain an electrostatic charge: by friction or by contact with another object that is already charged.

The Van de Graaff generator was first built in 1929. Its purpose was to smash atoms to find out more about them. A static charge builds up on the dome. A student's hair can stand on end in an experiment with the Van de Graaff generator because the strands of hair all carry like charge.



By friction

Rubbing a neutral material against another can add or remove electrons. When you rub a plastic ruler with wool, for example, electrons from atoms on the surface of the neutral wool are forced onto the neutral plastic ruler. The wool, having lost electrons, becomes positively charged. The plastic ruler, having gained electrons, becomes negatively charged.

By contact with a charged object

If a neutral material is touched by a charged object, electrons can be transferred from atoms on the surfaces of the two objects. When the charged object is removed, the previously neutral material has gained or lost electrons and so becomes charged itself. The student touching the dome in the photograph above becomes charged by contact and loses electrons to the dome. The student's hair stands on end, as the positively charged strands repel one another.

Electrons are the easiest particles to add to or remove from atoms, because they are not held tightly in the nucleus as protons are.

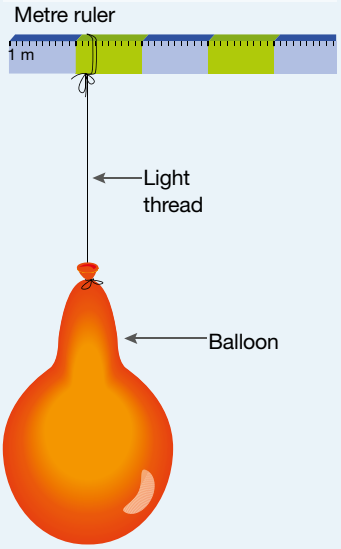
INVESTIGATION 7.12

The attraction of electricity

AIM: To investigate forces from electrostatic charge

You will need:
2 balloons
light thread
woollen cloth
metre ruler

Suspend a balloon from a metre ruler.



- Suspend one balloon from the metre ruler with light thread, as shown in the diagram.
- Rub the balloon with a woollen cloth.
- Remove the woollen cloth and then place it close to, but not touching, the part of the balloon that was rubbed. Observe any movement of the balloon.
- Suspend a second balloon from the metre ruler so that it is close to, but not touching, the first balloon.
- Rub each of the balloons with a woollen cloth — rub on the surfaces that are facing each other.
- Remove the cloth and position the balloons so that they are as close together as possible without touching each other. Observe any movement of the balloons.

Discussion

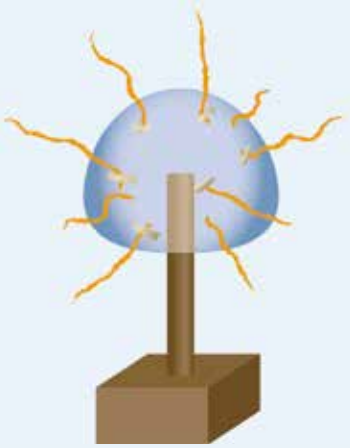
1. Describe the movement of the single balloon.
2. Does the balloon have the same charge as the woollen cloth after it is rubbed? Explain.
3. Describe the movement of the two balloons.
4. After being rubbed with the woollen cloth, do the balloons have like or unlike electric charges? Explain.
5. Copy and complete the following sentences by choosing the correct word from the pair of underlined words.
   Objects with like charges attract/repel each other.
   Objects with unlike charges attract/repel each other.

INVESTIGATION 7.13

The Van de Graaff generator

AIM: To investigate electrostatic charge

CAUTION: Your teacher will carry out this activity. Do not touch the charged dome of a Van de Graaff generator unless instructed to by your teacher. Always use an earthed rod to discharge. Carry out the demonstration while standing on a plastic tray.



You will need:
Van de Graaff generator
several strands of wool
plastic tray

Part A

- Turn the Van de Graaff generator on and let it charge up. Bring the **earthed** metal rod near it.
- Turn the generator off and discharge it using the earthed metal rod.

Part B

- Tape several strands of wool onto the dome. Make sure they are spread out over the surface of the dome. Turn the generator on and let it charge up once more.

Discussion

1. What do you observe occurring between the rod and the dome when it is turned on?
2. Explain your observation. Use words like charging and discharging in your explanation.
3. What happens to the wool?
4. Explain why this happens in terms of the charges on the dome and on the wool.
5. The wool forms a pattern around the dome. Explain why this pattern forms.

7.5.4 When lightning strikes

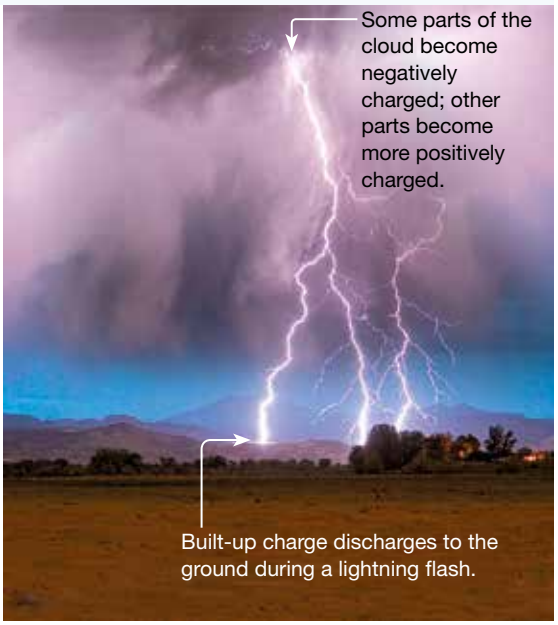
The particles of water and ice inside clouds are constantly moving against each other. Their movement causes charge to build up in the cloud. Some parts of the cloud become more negative, while other parts become more positive.

The charges keep building up. Eventually, there is so much charge built up in part of the cloud that it quickly discharges to another cloud or to the ground below. The result is the spectacular spark we call **lightning**.

If a bolt of lightning strikes a building, it can cause a huge amount of damage. Lightning takes the easiest path to the ground, so **lightning rods** are attached to the top of tall buildings. It is more likely that lightning will strike the rod, keeping the rest of the building safe.

Although lightning is spectacular to watch, it can also be very dangerous. Make sure you do not talk on the telephone during an electrical storm. Lightning can strike the phone line and travel to phones on the line. Mobile or cordless phones are much safer. It is also unsafe to be outside during an electrical storm. Take shelter inside a building or in a car. Never take shelter under trees, as they are often struck by lightning.

The heat created during a lightning strike heats the nearby air to a very high temperature. The air suddenly expands and produces the crashing sound we know as thunder.



7.5.5 When getting out of a car is a hazard

A moving car is a great charge builder. As a car moves, its body rubs against the air and its tyres rub against the road. The rubbing can cause charge to build up on the car and its passengers. As you get out of the car and go to touch the metal body, a spark crosses the small gap between your hand and the metal just before you touch it.

HOW ABOUT THAT!

Static electricity is a hazard in an operating theatre. Charge can build up on blankets and discharge quickly, causing a spark. Many of the instruments used in an operating theatre can also create sparks. This is very dangerous because operating theatres use gases that could easily explode. Doctors and nurses wear gowns made from natural fibres that do not build up electric charge easily. The patient and all of the equipment are earthed. An object is earthed when it makes contact with the ground. By earthing the patient and any equipment, charge flows to the ground before it can build up and cause a spark.

When cleaning makes things dusty

When you use a cloth to wipe over furniture it can sometimes make matters worse. Rubbing leaves the surface with a static charge that can attract small dust particles in the air. The dust particles are neutral and will be attracted to either a positive or negative charge left on the furniture.

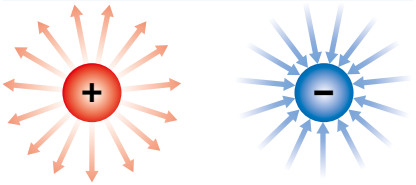
Using a furniture polish reduces the attraction between the furniture and dust particles by helping any built-up charge to leak into the air.

7.5.6 The electric field

A charged object can push or pull other charged objects near it. Like charges repel one another while oppositely charged objects attract one another. These forces of attraction and repulsion do not rely on contact

between the two charged objects, just as two magnets do not need to be touching to exert a force on each other. In the same way that magnetic fields are used to explain how magnetic forces can exist without contact, electrostatic forces can be explained by electric fields. The area around charged objects carries an electric field. The electric field lines are closest together near the charged object where the force is strongest.

The electric fields around a positive and a negative charge. The field lines show the direction of the force that would be applied to a small positive charge if it were placed in the field.



But it wasn't charged!

Charged objects and neutral objects can also be attracted to each other. A charged plastic pen attracts a neutral stream of water. A charged balloon sticks to a neutral wall. A charged comb will make dry hair stand up. The illustration below shows how a negatively charged plastic pen is able to pick up a small, neutral piece of paper.

Only a few charges have been labelled in the illustration. In reality there would be billions of them. The labelled charges are there to show whether an object is neutral or charged, and how the charge is distributed in the object.

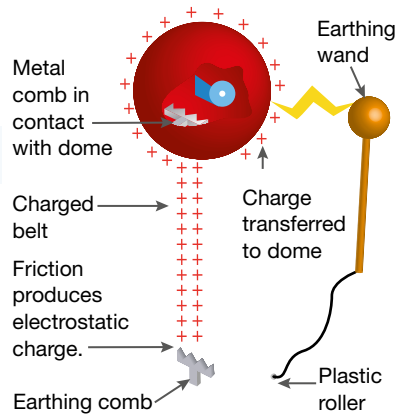
When the negatively charged pen is close to the paper, electrons are repelled from the top surface of the paper, leaving the surface with a positive charge. Note that the whole piece of paper is still neutral. If there is enough charge and the pen is close enough to the paper, the force of attraction is great enough to pull the paper up. Once the paper is touching the pen, the charge moves across and arranges itself so that it is evenly spread out.

7.5.7 Standing still

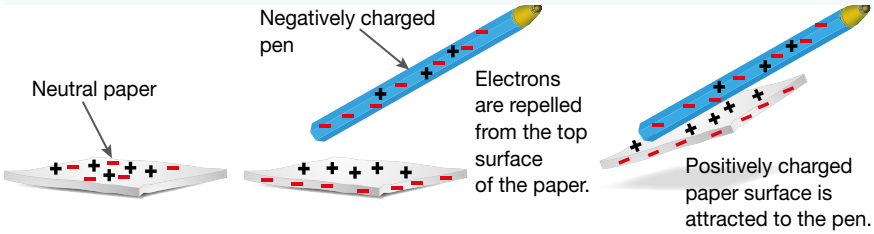
The **static electricity** that builds up on plastic rulers, balloons and the Van de Graaff generator when charged can leak slowly away from these objects to the air around them. When a large electric charge moves from one charged object to another object, a spark may be seen discharging between the two objects. A Van de Graaff generator can be used to demonstrate this.

A Van de Graaff generator has a large rubber belt held tightly between two plastic rollers. When the motor is turned on, the belt rotates. As the moving belt rubs over the lower roller, a charge is transferred from the roller to the rubber belt by friction. The charge on the rubber belt is then transferred to the metal dome via the upper metal comb. This leaves the dome with a built-up charge. Bringing a metal object, such as an earthing wand, near the dome allows electrons to flow to neutralise the charge on the dome, and this produces a spark. The spark you see is the dome discharging.

In a Van de Graaff generator, charge is transferred from the rubber belt to the metal dome. In this Van de Graaff generator, a positive charge builds up on the dome. A spark discharge can be produced if an earthing wand is brought near the metal dome.



Charged and neutral objects can be attracted to each other.



INVESTIGATION 7.14

Defying gravity

AIM: To investigate the forces resulting from electrostatic charges

You will need:

plastic ballpoint or felt-tip pen
woollen, cotton or nylon cloth
balloon

- Rub a plastic pen with a piece of cloth, then hold it near a thin stream of water from a tap.
- Describe what happens to the water.
- Rub an inflated balloon with the woollen cloth and place it against a wall.
- Does the balloon stick to the wall?
- If the balloon does not stick to the wall, try rubbing it with a different type of cloth.

Discussion

1. Explain the behaviour of the water and balloon in your own words.
2. Explain the effect of the cloth on the balloon.

Charge and discharge

Objects with the same charge *repel* each other while those with opposite charges *attract* each other. If sufficient charge builds up in oppositely charged objects, the force of attraction between the electric charges is so great that the electrons carrying this charge can jump across small air gaps. This discharge can also occur if one of the objects is neutral and so carries no overall charge. The earthing wand in a Van de Graaff generator is maintained at neutral when it is connected to the earth terminal in the base of the generator. Lightning strikes are electrical discharges between clouds carrying a huge static charge and the neutral ground below.

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. (a) **Identify** which two particles of an atom carry electric charge.
   (b) **Identify** which type of electric charge each of these particles carries.
2. When you rub a plastic ruler with a woollen cloth, the plastic ruler becomes negatively charged.
   (a) **Describe** what happens to the atoms in the cloth and ruler to cause this change.
   (b) Complete the following sentence.
   As the ruler becomes negatively charged, the cloth becomes _____ charged because it has more _____ than electrons.
3. Complete each of the following sentences by using the words ‘attract’ and ‘repel’.
   (a) Two positively charged objects would be expected to _____ each other.
   (b) Two negatively charged objects would be expected to _____ each other.
   (c) A positively charged object would be expected to _____ a negatively charged object.
4. **Explain**, with the aid of a diagram, how it is possible for a neutral object to be attracted to a charged object.
5. What is the release of built-up charge called?

Think

6. Illustrate the electric field around a positive charge and a negative charge that are placed near each other. (*Hint:* Think of the magnetic field between two unlike poles.)
7. Two balloons are hanging on threads next to each other, but not touching. They begin to move away from each other. If one of the balloons is positively charged, **identify** the charge of the other balloon.
8. **Explain** why the student touching the dome of a Van de Graaff generator on page 262 would be wearing rubber-soled shoes and standing on a plastic mat.

9. Work out from the following list of observations whether balloons A, B, C, D and E are positively or negatively charged.
   - Balloon E is positively charged.
   - Balloon B repels balloon D.
   - Balloon D is attracted to balloon E.
   - Balloon C repels balloon A.
   - Balloon A is attracted to balloon B.
10. Draw a labelled diagram to show how a neutral stream of water from a tap is attracted to a charged plastic pen. Use the symbols + and – to represent positive and negative charge.

Investigate

11. Have you ever heard a crackling sound when you remove your clothes at night? What causes it? Design and carry out an investigation to test which types of clothes are most likely to cause the crackling.
12. Search the internet to find out how many people are struck by lightning each year in Australia.

Create

13. Devise a model, using people to represent positive and negative charges, to show how objects become positively and negatively charged. Use your model to **demonstrate**:
    (a) whether a neutral object contains any electric charges
    (b) what must happen to make an object
        (i) negatively charged
        (ii) positively charged.

learnON RESOURCES — ONLINE ONLY

Watch this eLesson: Producing static electricity (eles-0067)

Complete this digital doc: Worksheet 7.6: Positive and negative (doc-12400)

Complete this digital doc: Worksheet 7.7: Charging up! (doc-12401)

Complete this digital doc: Worksheet 7.8: Attraction and repulsion (doc-12402)

7.6 Gravitational forces

7.6.1 Gravity everywhere

Gravity is the force that ensures that what goes up must come down. It pulls us down towards the Earth, pressing our feet onto the ground, which results in the friction that gives us traction. Gravitational forces are present throughout the universe, holding the moon in orbit around the Earth, and the Earth in orbit around the sun. It is a force that acts between any pair of objects, whether they are in contact or not. Gravity is therefore an example of a non-contact force.

No matter how large or small, all objects attract each other with a gravitational force. Gravity is actually a very, very small force. Even though all objects are attracted to each other, the effect is felt only when at least one of the objects is **massive** — as massive as a planet, moon or star. The bigger the mass of an object, the greater the gravitational force it pulls with.

The force of gravity between you and the wall is very small because both you and the wall have relatively small masses. You can't see the effect of gravity in this case. The force that attracts you to the Earth and the Earth to you is much bigger. You can see the effect of this force, especially if you fall! The gravitational force of the Earth is directed towards the centre of the Earth.

If it weren't for gravity, the moon would fly past us. The gravitational attraction between the Earth and the moon keeps the moon in orbit around the Earth.



7.6.2 Weight and mass

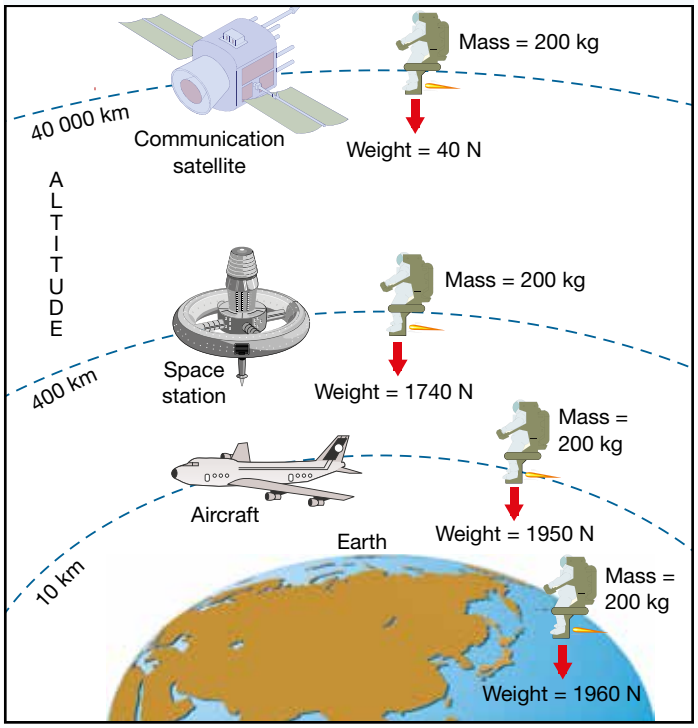
You might be surprised to know that mass and **weight** are two different things. Mass measures how much matter a substance contains. Regardless of where you are on the Earth, moon or Mars, your mass does not change. Mass is usually measured in **kilograms (kg)**, although other units such as tonnes and grams are often used.

Weight, on the other hand, is a measure of the size of the gravitational force acting on you. Weight is a force so, like other forces, it is measured in newtons (N). Objects of greater mass have a greater weight. For example, a student with a mass of 60 kg has a weight of almost 600 N, while a student of mass 50 kg has a weight close to 500 N.

Wherever you go in the universe, your mass is always the same, but your weight depends on the size of the gravitational force acting on you. This gravitational force depends on:

- the mass of the object pulling on you. Your weight on Earth is greater than it would be on the moon because the Earth is so much larger than the moon.
- how close you are to the object pulling on you. The weight of an astronaut, for example, decreases with increasing altitude.

Weight decreases with altitude while mass stays constant.



Weight can be measured with a spring balance like the ones shown on page 244. The weight of the object being measured pulls down on the spring and stretches it, moving the pointer over the scale.

INVESTIGATION 7.15

Measuring weight

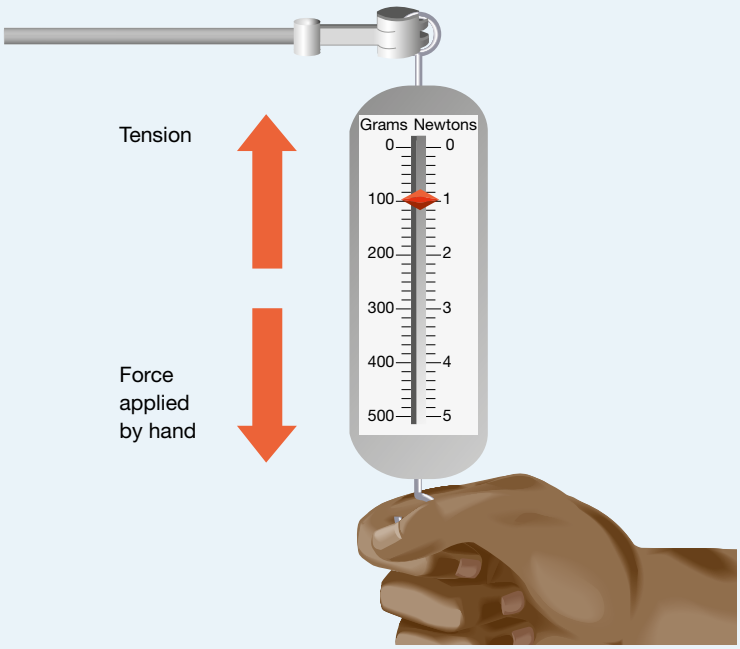
AIM: To investigate the effect of mass on weight

You will need:

5.0 N spring balance
mass carrier and 50 g slotted masses
retort stand, bosshead and clamp

- Pull down on the hook of a 5.0 N spring balance until it reads 1.0 N. There are two forces acting on the hook. As long as the hook is not changing its motion, the upward force of tension is the same as the downward pull of your hand.
- Pull the hook down until the spring balance reads 2.0 N. The downward pull has doubled.
- What effect has doubling the tension force had on the distance that the spring has stretched?

A spring balance. There are two forces acting on the hook.



A spring is a good force measurer because, if the pulling force on it doubles, the distance stretched doubles. If the pulling force triples, the distance stretched triples.

- Hang the spring balance from a clamp fixed to a retort stand and adjust the pointer so that it reads zero.
- Attach a 50 g mass carrier to the hook of the spring balance and record its weight in newtons in the table below. Calculate and record the mass in kilograms by dividing the mass in grams by 1000.
- Add 50 g masses, one at a time, until you have a total mass of 400 g. Each time, record the mass in kilograms and weight in newtons.

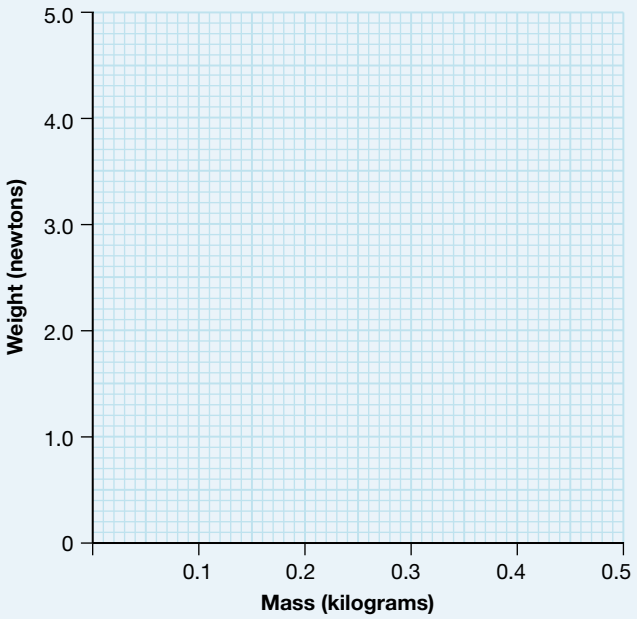
Measuring weight

Mass (g)	Mass (kg)	Weight (N)
50	0.05	
100	0.10	
150	0.15	

Discussion

1. Does the spring increase its stretch by the same amount each time a 50 g mass is added?
2. How would your results be different if you conducted this activity on Mars?
3. Use your results to complete a copy of the graph below.

Graph of weight measured on a spring balance versus mass

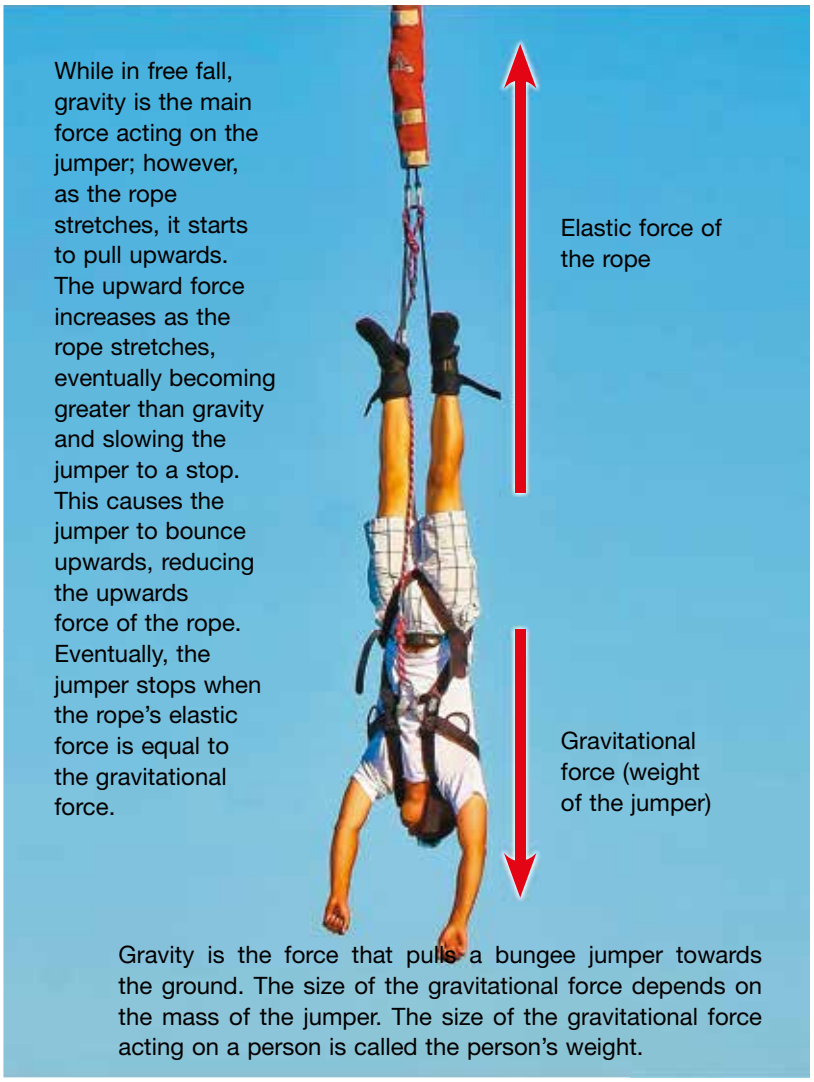


4. Draw a line through the points that you have plotted and continue your line to where you think it should be if you measured the weight of a mass of 500 g. This process is called *extrapolation*.
5. Is your line straight? Should it be straight?
6. What trend is revealed by your line graph as the suspended mass is increased?
7. What does your graph tell you should be the weight of a 500 g mass? Measure it and see how accurate your prediction is.
8. How could you predict the weight of an object if you knew its mass?

7.6.3 Balanced and unbalanced gravitational forces

Gravity is a force that acts on you all the time. When you are standing up, this pull of gravity, also called weight, is balanced by the force of the ground pushing back up on you. You may not notice this force, but after standing up a long time your muscles may be sore from supporting your weight. These balanced forces cause you to be stationary.

Unbalanced forces on the other hand cause objects to speed up, slow down or change direction. In bungee jumping, the two main forces acting on the jumper are the gravitational force acting downwards and the bungee rope's elastic force pulling up. The staff managing the bungee jump select the appropriate equipment for the size of the jumper. The mass of the person jumping determines which rope will be used. The ropes have different thicknesses to suit the weight of the jumper.



Gravity is the force that pulls a bungee jumper towards the ground. The size of the gravitational force depends on the mass of the jumper. The size of the gravitational force acting on a person is called the person's weight.

HOW ABOUT THAT!

Isaac Newton (1643-1727) was an English mathematician, physicist, astronomer and philosopher. You might know him as the guy who sat under the apple tree and, after being struck on the head by a falling apple, discovered gravity. While this is a commonly believed story, scientists aren't convinced it happened that way. Many scientists and historians believe that Newton was looking out of the window when he saw the apple fall.

At this point he was struck with a realisation — apples (and everything else) always fall down, not up or sideways. He wondered about the force that caused this to happen. He wondered what would happen if the tree were much taller. In fact, he was able to deduce, after much time and many calculations, that the force that caused the apple to fall was the same force (gravity) that kept the moon in orbit around the Earth. From these ideas, Newton wrote his Law of Universal Gravitation, which describes how gravity acts in all places, not just on Earth.

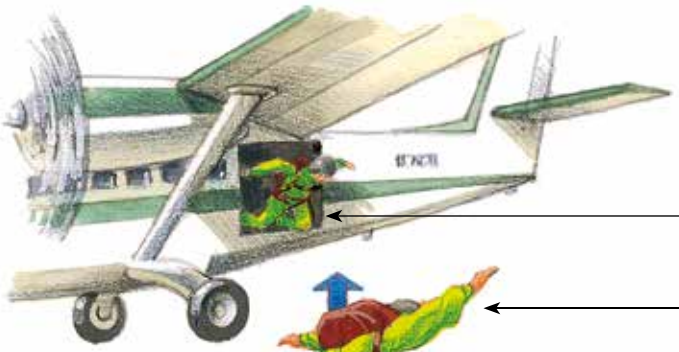
Newton was able to explain many observations, including falling apples, tides and orbiting planets with a single law of gravity.

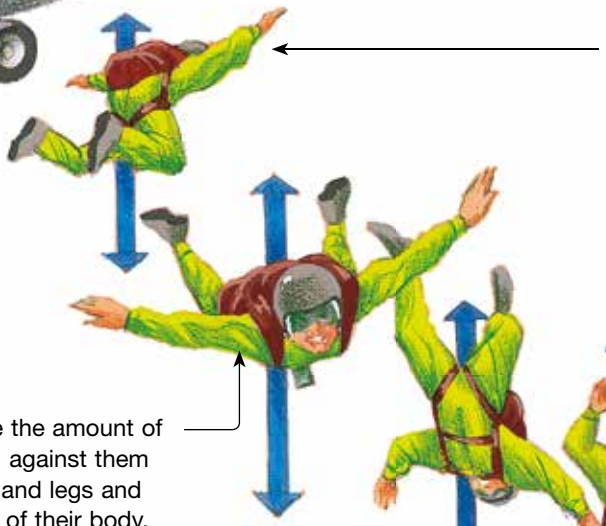


7.6.4 Forces involved in skydiving

There is something about falling through the air at 190 km/h that really gets the adrenalin pumping! Skydiving is an activity that is enjoyed by thousands of thrill seekers around the world and is an important part of military and rescue services.

1. Skydivers can jump from various heights, but most beginners jump from about 4 kilometres above the ground. When the plane is over the jump site, the skydiver leaps from the plane. Beginners are taught to release their parachute as soon as they are clear of the plane. More experienced divers free-fall for some time before opening their parachute.

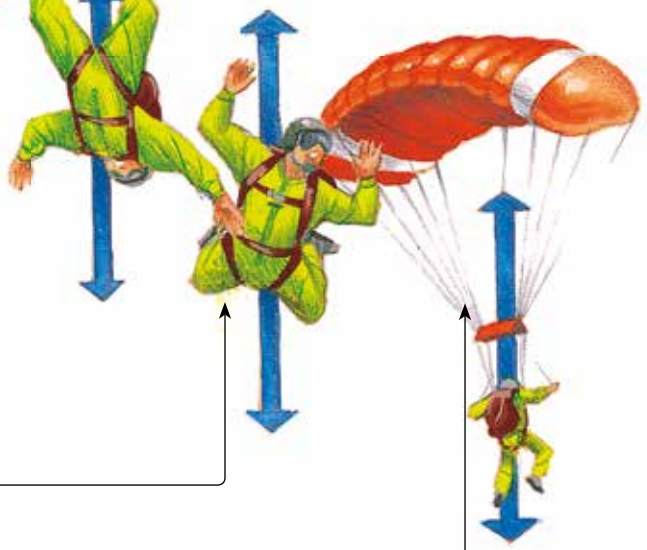




2. When skydivers jump from a plane, the Earth's pull of gravity causes them to fall with increasing speed towards the ground. Near the start of the jump, a diver does not fall very quickly. At this point in the jump, the diver does not experience much air resistance. But, as the diver's speed increases during the fall, so does the size of the air resistance pushing against them.

3. Skydivers can change the amount of air resistance pushing against them by moving their arms and legs and changing the position of their body. By lying flat, with their arms and legs out, divers increase the air resistance pushing against them. This position decreases their acceleration. With their legs straight up and their head down, a diver falls at a faster rate. This explains how one skydiver can catch up with another.

4. During a jump, a skydiver falls faster and faster. The air resistance pushing against a diver gets bigger and bigger as the speed increases. Eventually, the upward push of the air resistance and the downward pull of gravity are balanced. When this happens, the diver falls at a steady speed. This steady speed is called terminal velocity. The terminal velocity of a skydiver without a parachute is very fast. A diver could not land safely at this speed, so a parachute is needed.



5. When the parachute opens, a huge air-resistance force pushes against it. When the parachute first opens, the air resistance is larger than the gravity force pulling the skydiver down, so the diver slows down. The skydiver reaches a new, slower terminal velocity soon afer the parachute opens.



6. The skydiver lands safely at the drop zone.

INVESTIGATION 7.16

The landing time of a parachute

AIM: To investigate the effect of one of the following factors on the landing time of a parachute

(a) Mass of the skydiver
(b) Size (area) of the canopy
(c) Shape of the canopy

You will need:

plastic from freezer bags
scissors
large paperclips
plasticine
stopwatch
cotton or nylon thread
metre ruler

Use plastic from freezer bags to make the canopy. Cotton or nylon thread can be used to hold a model skydiver, which could be constructed using paperclips and plasticine.

- Ensure that you do each of the following:
  - Keep all things constant except the factor that you are deliberately changing, so that your tests are fair. This is called **controlling variables**.
  - Repeat your measurement of landing time at least three times and calculate an average.
  - Draw up a table like the one below in which to record your results from testing the mass of the skydiver, the area of the canopy or the shape of the canopy.

	Time taken to land (seconds)			
Variable tested	**Trial 1**	**Trial 2**	**Trial 3**	**Average**

Discussion

1. Write a report of your investigation using the headings Aim, Materials, Method, Results, Discussion and Conclusion.
2. In your discussion, analyse your results and comment on how your design could be improved.
3. As an extra challenge after the investigation has been completed, see who can make the parachute that takes longest to reach the floor with a standard mass of paperclips and plasticine from a height of 2 metres.

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 difference between mass and weight.
2. **Identify** the unit of measurement for:
   (a) mass
   (b) weight.

3. The force of gravity is not the same on all objects. What does it depend on?
4. In which direction does the Earth's gravitational force act?
5. **Explain** whether your mass would change if you were to visit the moon. What about your weight?
6. **Identify** what causes the moon to orbit the Earth.

Think

7. When you drop a nail and a feather from the same height, they reach the ground at different times. **Explain**, with the aid of a diagram, why this is the case.
8. A falling table tennis ball reaches its terminal speed quite quickly. A falling golf ball takes a long time to reach its terminal speed. **Explain** why.
9. 'Gravity exists between two objects only if at least one of them is massive.' Is this statement true or false? **Explain** your answer.
10. **Identify** the largest force acting on a bungee jumper:
    (a) when the rope is slack
    (b) while slowing down.
11. The weight of a 3 kg brick is 30 newtons. **Predict** the weight of a 6 kg brick.

Investigate

12. Would a rubber band be as effective as a spring in a force measurer? Design and conduct an experiment to find out. You will need to **construct** a table and a graph.

Imagine

13. Imagine that you are working on the first space laboratory on Mars. The pull of gravity is a little more than one-third of what it is on Earth. Write a diary entry for your very first working day in the laboratory. Your diary entry should be an account of your day from 6 am when your alarm rings until 10 pm when you go to bed. Emphasise the effects of less gravity and don't forget that you need to keep physically fit. Discuss your writing with a partner.
14. Use the **Bungee game** weblink in the Resources tab to simulate a successful bungee jump. Set your mass, rope length and dimensions, and try to achieve the right drop.
15. Use the **Coaster game** weblink in the Resources tab to design your own roller coaster. Set the sizes of your hills and loops, the initial speed and mass of your coaster, and the amount of gravity and friction at work.

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Complete this digital doc: Worksheet 7.9: Gravity (doc-12403)
Explore more with this weblink: Bungee game
Explore more with this weblink: Coaster game

7.7 Buoyancy and surface tension

7.7.1 Buoyancy

Large ferries and cruise ships can carry hundreds of passengers and the ferry itself can have a mass of several thousand kilograms. How are they able to stay afloat? The weight of the ship is balanced by a buoyancy force.

The buoyancy force is the upward push on an object that is at least partially submerged in a fluid like a liquid or a gas. The hull of the ship is hollow, making the ship and passengers lighter than the mass of the water that it displaces (takes the place of). Helium-filled party balloons float in air because the buoyancy force is greater than the gravitational force on the balloons.

The buoyancy force helps this heavy cruise ship, the *Queen Victoria*, to stay afloat.



Helium-filled party balloons have a large buoyancy force.



INVESTIGATION 7.17

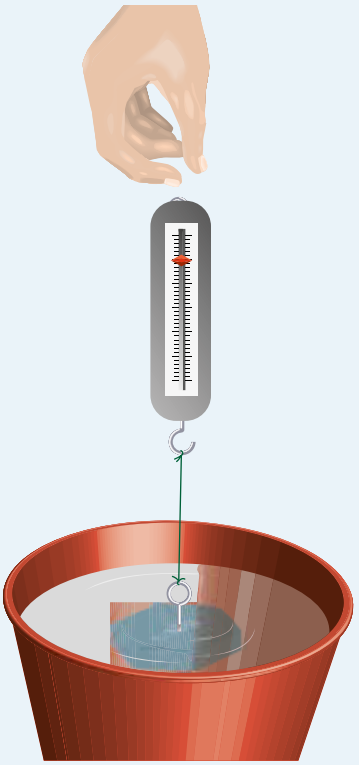
Are things really lighter in water?

AIM: To determine the buoyancy force of a submerged object

You will need:

500-gram mass
length of string
spring balance
ice-cream container or bucket

- Tie some string around a 500-gram mass and attach it to a spring balance.
- Use the spring balance to find the weight (in newtons) of the 500-gram mass and record it in a suitable table.
- Suspend the 500-gram mass in a container of water without letting it touch the bottom and record its weight while suspended in water.
- Calculate the size of the buoyancy force by subtracting the object's weight in the water from the object's weight in air, and record this in your table.



Discussion

1. What was the magnitude of the buoyancy force?
2. Draw a diagram of the 500-gram mass being suspended from a string in water. Draw and label arrows to indicate the forces acting on the 500-gram mass. How did you show that the upwards and downwards forces were balanced?

7.7.2 Surface tension

Have you ever seen an insect make its way along the surface of a pool of water? Water striders are particularly good at this. What prevents insects like water striders from sinking into the water? The water particles have a force of attraction between them called cohesion. This force of attraction on the surface of water is called **surface tension**.

Surface tension sometimes gives water the appearance of having a transparent 'skin'. While the surface tension is not very strong, it is strong enough to prevent light objects from falling through the surface of the water.

Water striders use surface tension to walk on water.



Surface tension prevents water on this coin from overflowing.



INVESTIGATION 7.18

Try your hand

AIM: To demonstrate the effect of surface tension

You will need:

eye-dropper
a large coin

Compete with others in the class to see how many drops of water you can fit on a coin without it spilling off.

- Work in pairs. One partner carefully adds water to the surface of a large coin, drop by drop. The other partner counts the drops until the water spills off the coin.
- Swap roles so your partner takes a turn. Record your team's average.
- Tabulate the average of each team in the class.

Discussion

1. For this to be a fair competition, what variables must be controlled?
2. Explain why you can fit so many drops on the coin without it overflowing.
3. Select an appropriate type of graph to present the class results.

INVESTIGATION 7.19

A Cartesian diver

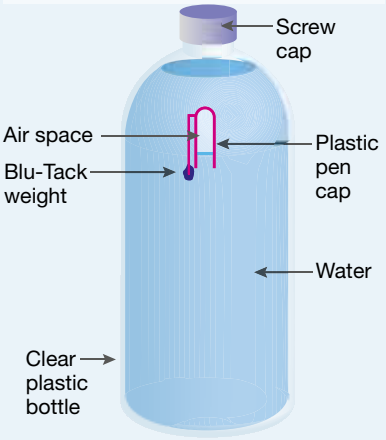
AIM: To build a Cartesian diver

You will need:

clear plastic soft-drink bottle and screw cap
Blu-Tack
plastic pen cap

- Fill the plastic bottle almost to the top with water.
- Attach a small piece of Blu-Tack to the clip of a plastic pen cap.
- Place the cap in the bottle so it floats, and seal the bottle tightly.
- Squeeze the sides of the bottle and observe the motion of the suspended 'diver'. You may need to readjust the size of the piece of Blu-Tack attached to the pen cap.
- Record your observations.

The Cartesian diver



Discussion

1. Draw and label the forces on the Cartesian diver before and after the bottle is squeezed.
2. Explain how the Cartesian diver works.

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. Name two forces acting on you when you float on your back in a swimming pool.
2. Name the force that keeps a water strider on the surface of water.
3. **Explain** the difference between buoyancy and surface tension.

Think

4. Which fluid produces the greater buoyancy force — air or water? How do you know?
5. **Outline** what happens to an object when you plunge it into a fluid and let go:
   (a) if the buoyancy force is the same as its weight
   (b) if the buoyancy force is less than its weight.
6. **Explain**, in terms of gravity, buoyancy and surface tension, why humans can't walk on water.

Investigate

7. Design and carry out an experiment to compare the buoyancy and surface tension of water, olive oil and vinegar.

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Complete this digital doc: Worksheet 7.10: Buoyancy (doc-12404)

7.8 Using technology to reduce the impact of forces

Science as a human endeavour

7.8.1 Safer cycling

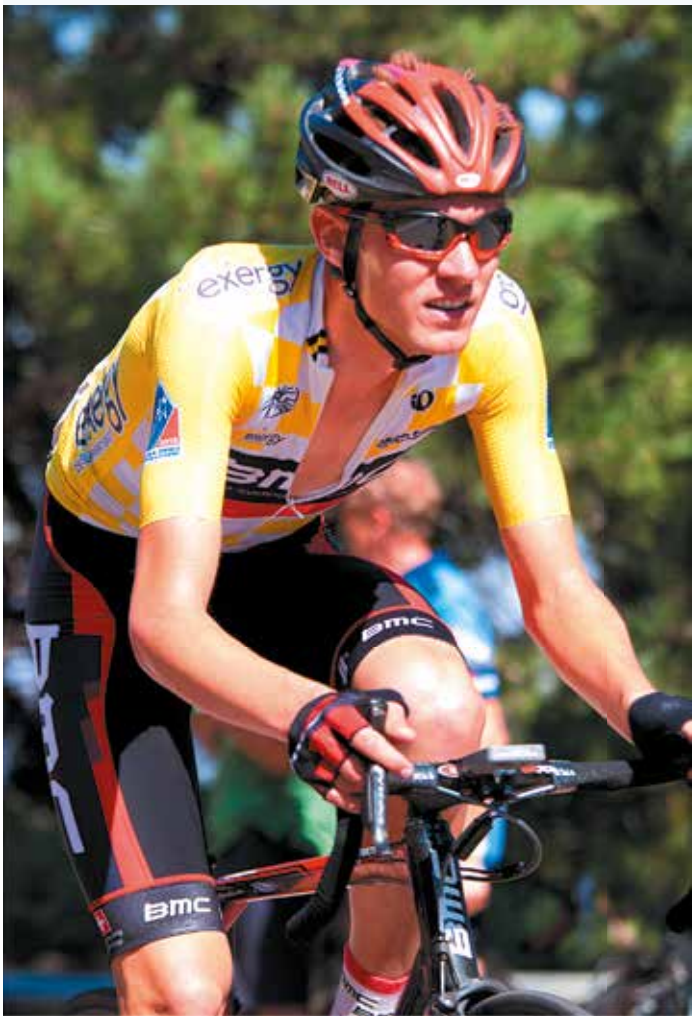
Every year in Australia, over 1200 people die as a result of road crashes. Many of the deaths and injuries can be avoided.

Bicycle riders account for well over one-third of the road crash injuries in people aged up to 16 years. The most serious injuries tend to be to the head and face. The wearing of bicycle helmets has greatly decreased the number of head injuries to cyclists.

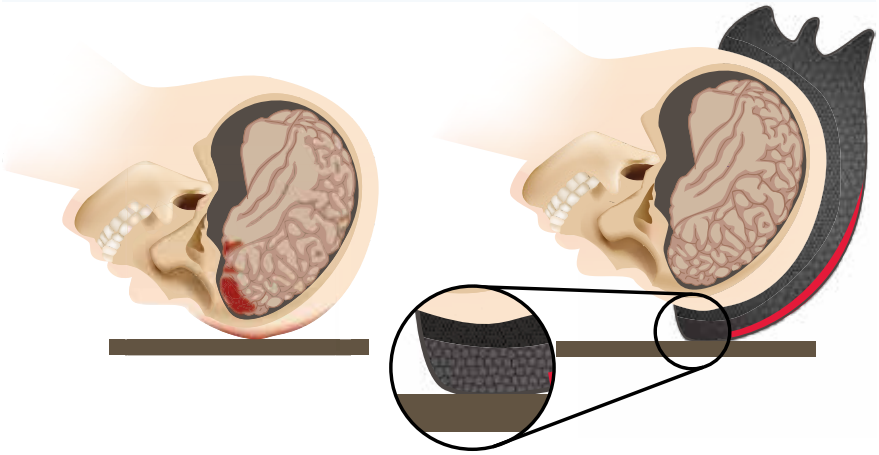
A bicycle helmet has a layer of polystyrene foam at least one centimetre thick inside a shell of hard plastic. A cyclist's head falling to the road hits the ground at speeds of up to 20 kilometres per hour. Without a helmet, a sudden impact with the ground can cause serious head injuries. With a helmet, the impact force on the head is smaller as the plastic shell and polystyrene foam are crushed, and so the injuries are less severe.

Cycling isn't the only sport where you need a helmet. Other activities in which helmets soften the impact of a fall or collision include motorcycling, horse riding and a wide range of sporting activities.

A bicycle helmet is required by law.



The plastic shell and polystyrene foam of a helmet soften the impact on the head in an accident.



INVESTIGATION 7.20

Egghead

AIM: To model a bicycle helmet during a collision

You will need:

hard-boiled egg
selection of packing materials, such as bubble wrap, foam rubber and newspaper
sticky tape
cardboard
wire

- Design, build and test a container that will protect a hard-boiled egg in a collision.
  Your aim is to create an egg container that will prevent the shell from cracking when it is dropped from a height of several metres onto a hard floor.
  You are actually creating a model of a bicycle accident. The egg represents the head of a cyclist. Your container represents the helmet.

Discussion

1. Draw a neat, labelled diagram of your egg container.
2. Explain how each feature included protected the shell from cracking.
3. If your 'egg head' was 'injured', suggest how you could improve the effectiveness of your 'helmet'.

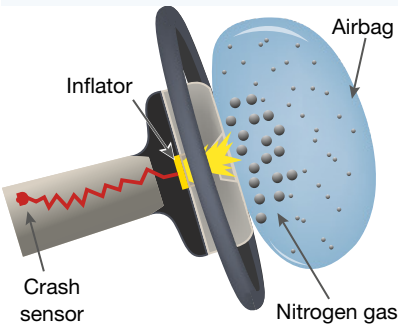
7.8.2 Airbags



Airbags are an important safety feature of modern vehicles. They are designed to cushion the driver and passengers from the force of impact during a crash. Many vehicles today contain multiple airbags to protect occupants from both frontal and side collisions. During a frontal crash, your seatbelt restrains your lower body and torso, but the frontal airbag helps protect your head and chest. Without airbags many more severe injuries would occur from the upper body striking the steering wheel or dashboard.

The **airbag** itself is made of a thin, nylon fabric. Frontal bags are folded into the steering wheel or dashboard and side airbags are contained in the seat or door. An electronic **sensor** detects the vehicle's rapid deceleration in a collision and causes the bag to inflate with nitrogen gas through a rapid chemical reaction. From the time the sensor detects the collision to the time the airbag is fully inflated is only 30 milliseconds, or 0.03 seconds, well before the car's occupant hits the airbag. The **powdery substance** released from the airbag is cornstarch or talcum powder, which is used by the airbag manufacturers to keep the bags pliable while they are stored ready for use.

Deployment of an airbag



7.8.3 Bend your knees

In some sports, like basketball and volleyball, you need to jump high above the ground. But, of course, what goes up, must come down. When you land on the ground, you stop because the surface provides a large upward force on you. If you land on your feet with your legs straight and rigid, you stop very quickly, but the upward force on your legs is large enough to cause damage to your knees and other joints. However, if you bend your knees as you land, you stop more slowly and the upward force on your body is reduced.

Well-designed sports shoes soften the impact of the wearer as they land on the ground after a jump. The shoes decrease the amount of jarring to the knees, ankles and the rest of the body. Air pockets in the soles of sports shoes slow the body down more gradually as the feet hit the ground. They also help reduce impact on the body during heel-to-toe walking action because air flows back and forth between the air pockets.

(a) Air pockets and (b) air springs in sports shoes help to reduce the impact on knees and other joints when running or jumping.

(a)



(b)



It's best to bend your knees when landing after a high leap.



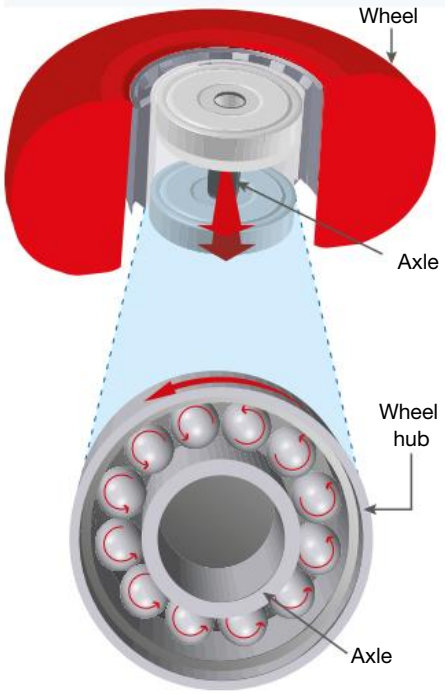
7.8.4 Reducing friction

Friction is useful if you want to get moving or if you want to stop. However, friction is a problem for moving parts in machines and other equipment. Wheels, like those on a skateboard, need to move freely around an **axle**. To achieve this, steel balls, called **ball bearings**, are inserted into the hub of the wheel. The bearings help the wheel roll around the axle, rather than slide over it. The rolling motion of the ball bearings helps to reduce friction — rolling objects experience less friction than sliding objects. **Lubricants**, such as grease, can be applied to the ball bearings to reduce friction even further.

The grease provides a slippery layer between the surfaces so that they move more easily. Without ball bearings and grease, the wheels would be difficult to turn and the components would wear out very quickly.

Friction between moving parts causes them to heat up; this is not good for a machine with moving parts.

Ball bearings help to reduce friction between the axle and the wheel hub of a skateboard.



7.8.5 Friction in fluids

Any substance that is able to take up the shape of its container and can flow is called a **fluid**. Air and water are both fluids. Objects travelling through air and water experience fluid friction. Fluid friction in air is commonly called 'air resistance' or drag. The term 'drag' can also be applied to fluid friction in water.

Like rolling friction and sliding friction, fluid friction acts against the motion of objects. Fluid friction limits the speed of objects travelling through air and water. It increases the amount of fuel needed by cars, planes, motorised boats and submarines.

Cars, planes, watercraft and bicycles are streamlined to reduce fluid friction. The faster a vehicle needs to travel, the more important streamlining becomes. Some athletes even shave their bodies to streamline them.



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. **Explain** how bicycle helmets protect the head in a car crash.
2. **Explain** why you should bend your knees when landing after leaping high to shoot in basketball.
3. **Describe** the likely motion of an unrestrained rear seat passenger in a car that collides with a tree at 60 kilometres per hour.

Think

4. When a stationary car is hit from the rear by another vehicle, it is pushed forwards rapidly. **Describe** the likely motion of a front seat passenger:
   (a) with a head rest fitted to the seat
   (b) without a head rest fitted to the seat.
5. List as many sports as you can in which helmets are worn to protect participants from head injuries.

Create

6. Design a poster with the title 'Don't be an egghead. Wear a helmet.'

Investigate

7. Take a look at your sports shoes and **describe** features that are designed to soften the impact on your foot.
8. Visit a government website containing car crash statistics. **Analyse** whether road safety campaigns are succeeding in reducing injuries.

7.9 Review

7.9.1 Study checklist

Forces

- **identify** the forces acting around us 7.2–7.7
- **identify** changes that take place when particular forces are acting 7.2–7.7
- **predict** the effects of balanced and unbalanced forces 7.2–7.7

Friction

- **analyse** situations where friction operates to oppose motion and produce heat 7.3, 7.8
- investigate factors that influence the size and effect of frictional forces 7.3, 7.8

Magnetism

- **describe** the behaviour of magnetic poles when they are brought close to each other 7.4
- use the term 'field' in **describing** forces acting at a distance 7.4
- investigate how magnets and electromagnets are used in some everyday devices or technologies 7.4

Electrostatic forces

- **describe** how an object gains an electrostatic charge 7.5
- illustrate the electric field around charged objects 7.5
- investigate the behaviour of charged objects when brought close together 7.5
- **identify** everyday situations where the effects of electrostatic forces can be observed 7.5

Gravity

- **identify** that the Earth's gravity pulls objects towards the centre of the Earth 7.6
- **describe** situations where gravity acts as an unbalanced force 7.6
- **distinguish** between mass and weight 7.6

Buoyancy and surface tension

- **investigate** the forces of buoyancy and surface tension 7.7

Applications and uses of science

- **describe** examples of technological developments that have reduced the impact of forces in everyday life 7.8

Individual pathways

ACTIVITY 7.1
Investigating forces
doc-10553

ACTIVITY 7.2
Analysing forces
doc-10554

ACTIVITY 7.3
Investigating forces further
doc-10555

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FOCUS ACTIVITY

Design and carry out an experiment to **investigate** how the buoyancy force on a submerged object varies with the volume of that object. Create a presentation of your scientific report, displaying your findings in a table with an appropriate graph.

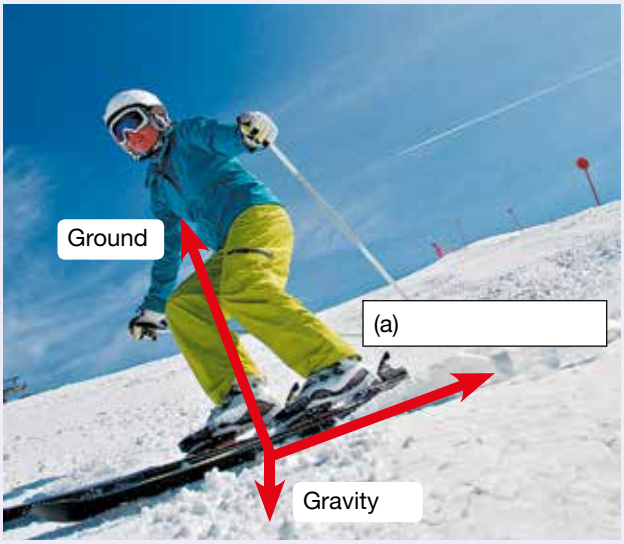
Access more details about focus activities for this chapter in the Resources tab (doc-10552).

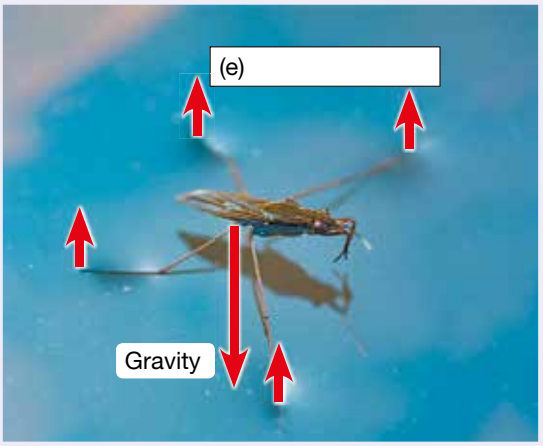
7.10 Review 1: Looking back

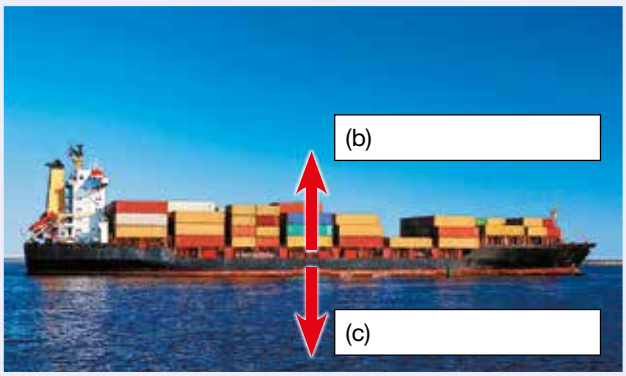
assessON

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.

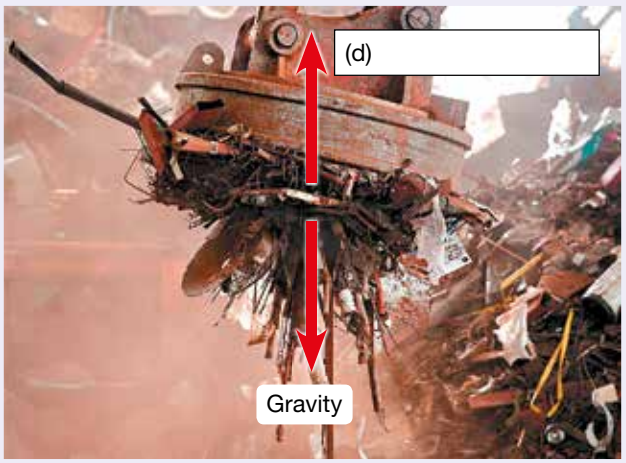
1. **Identify** the forces missing in each of the diagrams below.

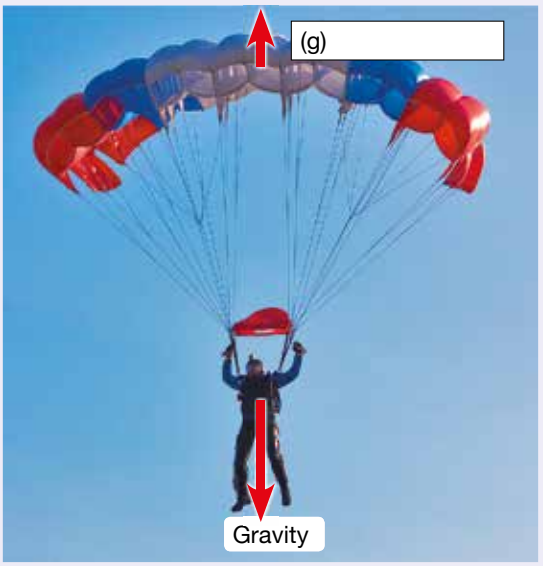




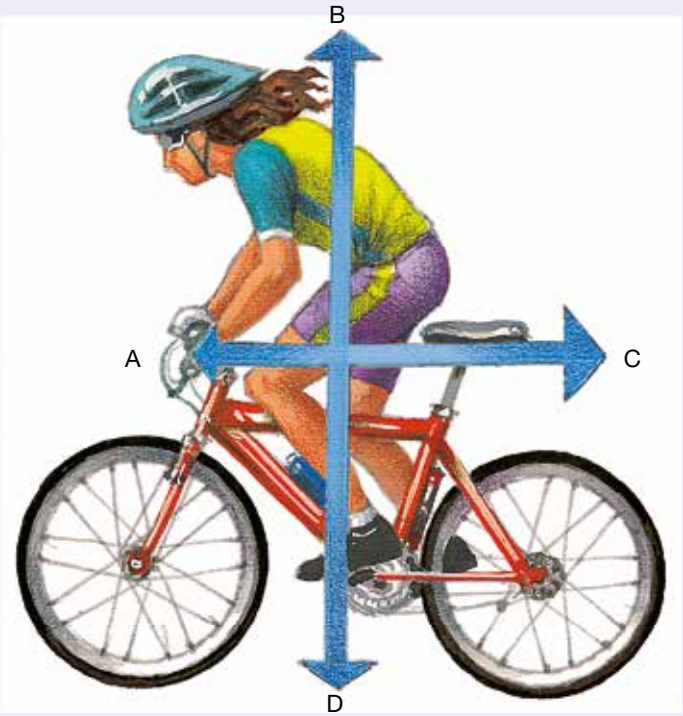






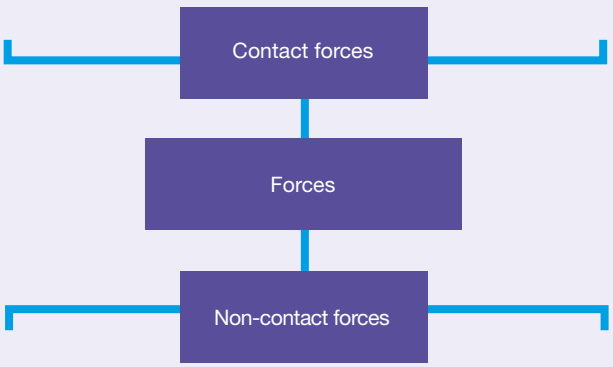


2. The arrows in the following diagram represent four of the forces acting on a cyclist riding on a smooth, flat surface.



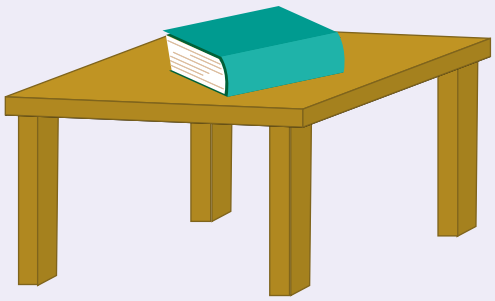
(a) Which two forces are equal in size?
(b) Which arrow could represent air resistance?
(c) Is the cyclist speeding up, slowing down or travelling at a steady speed? **Explain** your answer.

3. Name the force that acts against objects that are sliding past each other.
4. (a) Copy and complete the concept map below to show the types of forces described in this topic. Add as many examples of forces as you can to the map. Don't forget that you can sometimes make links between the different 'arms' of your concept map.
   (b) **Compare** and discuss your map with others in the class.
   (c) Add any further details you wish to your map following the discussion.
5. **Explain** why the pull of gravity is less on the moon than on Earth.



6. Friction can be useful or it can be a nuisance. List three situations in which:
   (a) friction is necessary
   (b) friction is a nuisance.

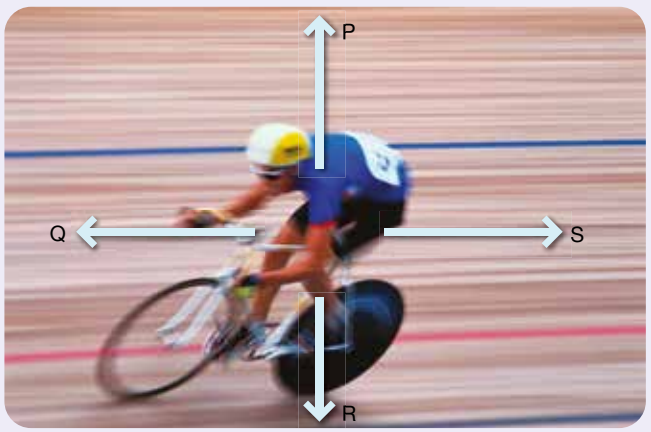
7. Redraw this diagram. On your sketch, include arrows to represent the forces acting on the book while it is at rest on the desk.



8. **Identify** the unit used to measure:
   (a) mass (b) weight (c) force.
9. **Explain** why you should avoid standing under trees in a thunderstorm.
10. When a plastic rod is rubbed with a certain cloth, the rod becomes positively charged. **Predict** the charge on the cloth.
11. State whether the following are true or false.
    (a) Objects with like charges attract.
    (b) Two neutral objects repel each other.
    (c) Neutral objects contain both negative and positive charges.
    (d) Objects with an overall negative charge still contain some positive charges.
    (e) If two objects repel, they must be positively charged.
12. A plastic spoon that has just been dried with a tea towel is placed near some pepper spilled on a kitchen bench. Some of the pepper is attracted to the spoon and sticks to it. **Explain** why this happens.
13. (a) As planes move through the air, they build up large amounts of static electricity. Suggest how this happens.
    (b) Before refuelling, a wire is used to connect the plane to the ground. **Explain** why this is important.

Test yourself

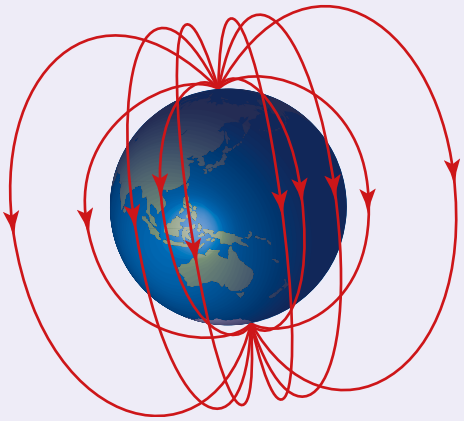
1. The four forces on the cyclist and bike, labelled P, Q, R and S, are respectively



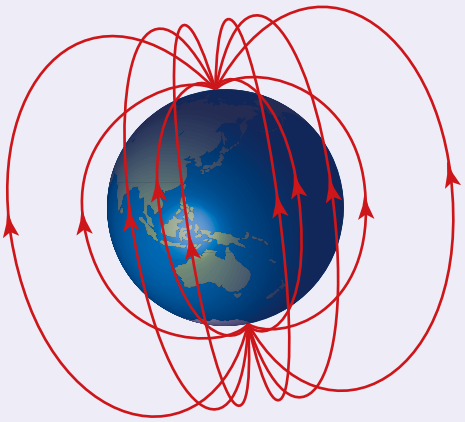
(A) force of the ground, forward push, weight and air resistance.
(B) air resistance, force of the ground, forward push and weight.
(C) air resistance, forward push, magnetic attraction and road friction.
(D) force of the ground, road friction, weight and air resistance. **(1 mark)**

2. The concept of a field is useful in explaining the
   (A) elastic force in a spring.
   (B) attraction of opposite magnetic poles.
   (C) push force on a shopping trolley.
   (D) unbalanced vertical forces on a kayak. **(1 mark)**
3. A rock was found to have a weight of 5.4 newtons. When submerged in water, its weight was found to be 4.2 newtons. The buoyancy force on the rock is
   (A) 1.2 N. (B) 4.2 N.
   (C) 5.4 N. (D) 9.6 N. **(1 mark)**
4. **Describe**, using examples, how technology can reduce the impact of forces in everyday life. **(6 marks)**
5. The Earth's gravitational field would be best represented as

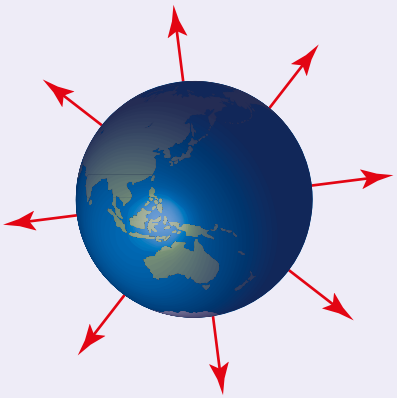
(A)



(B)



(C)



(D)



(1 mark)

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Complete this digital doc: Worksheet 7.11: Forces puzzle (doc-12405)

Complete this digital doc: Worksheet 7.12: Forces summary (doc-12406)

TOPIC 8
Body systems

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 human body is an amazing machine. In the few minutes it takes this professional swimmer to swim a lap, processes take place inside her body that allow her to propel her body through the water with maximum speed and power. In this topic you will learn about the systems that keep you alive and some of the things you can do to keep these working at peak capacity.

LEARNING SEQUENCE

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8.9	Have a heart	318
8.10	Getting rid of waste	324
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A competitive swimmer pushing her body to the limit



Know your body

As the swimmer shown on the previous page begins her lap, her breathing rate increases and she breathes more deeply to take in more air into her lungs. Her heart rate increases so that the oxygen in the air can be delivered to all cells of her body more rapidly. The diameter of some of her blood vessels increases to ensure that blood flow to the muscles that most need oxygen is maximised. In her muscles, glucose provides the energy. The glucose is burnt up so rapidly that a by-product called lactic acid forms, causing pain, but she pushes on regardless. All the systems that make up her body are working together to get her to the finish line.

1. Machines need a source of energy to keep running. What is the source of energy for the human body?
2. List some body systems you already know about.
3. Body systems are made up of organs. List two organs of the respiratory system and two organs of the urinary system.
4. Professional athletes do a lot of training. What changes to the athlete's body might result from this training? Which body systems are affected by the training?
5. List some diseases that affect the:
   (a) respiratory system
   (b) circulatory system.
6. What size and shape are your body parts? Think about the following items and how they might relate to the sizes of organs you may sketch in *Investigation 8.1*: an olive, your fist, your two fists touching together, a large grapefruit.
7. Have you ever heard the phrases, 'heart-shaped box' or 'kidney-shaped dish or swimming pool'? Some organs are often shown as stylised shapes. Discuss with a partner or your group what is wrong with the following images used to depict organs.

Is the heart located here? What size and shape is your heart?



This is a kidney dish but are the kidneys similar to this?



INVESTIGATION 8.1

Know your organs

AIM: To draw a diagram showing the locations and shapes of some of the organs of the human body

You will need:

sheets of butcher paper
marker pens
sticky tape or masking tape

- Tape the pieces of butcher's paper together.
- One group member lies on the butcher's paper with their arms slightly away from their body while another group member traces the outline of their body.

- Once the body outline is ready, work as a group to add the following organs to the diagram: heart, liver, intestines, stomach, lungs, bladder, uterus, kidneys, brain, ovaries, testes, oesophagus. Decide on the location, shape and size of each organ then draw them in.

Discussion

1. Compare your diagram with reference material. Which organs did you draw in the wrong positions? Did you estimate the sizes and shapes of the organs accurately?
2. Which system do each of the organs listed above belong to?
3. Would you normally find ovaries, a uterus and testes in the same body? Explain your answer.

Be careful when drawing around someone as you want to get a realistic outline — unlike the outline in this photo. The outline should be closer to the person's body shape.



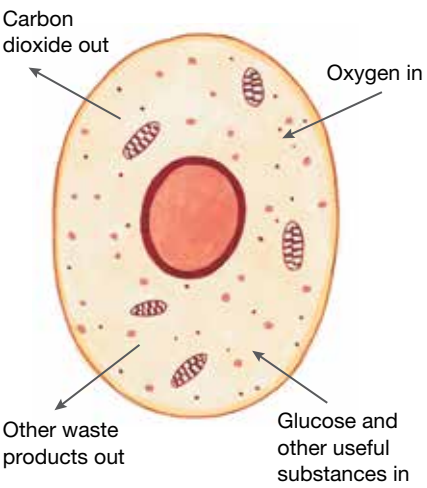
8.2 All systems go!

8.2.1 Diffusion

In topic 2, page 68, you learned that there are unicellular and multicellular organisms. Unicellular organisms are made up of one cell only. That one cell must do all the jobs needed to keep the organism alive. Unicellular organisms are very small so the substances they need, such as oxygen and glucose, can simply **diffuse** into the cell from its surroundings. Waste products can diffuse out of the cell and into the surroundings.

Multicellular organisms are made up of many cells. Some multicellular organisms such as flatworms and sea lettuce are very thin and many of their cells are in direct contact with their surroundings. Flatworms have some body systems, but they do not have a respiratory system. They use their whole body surface to take in oxygen from the water in which they live. Similarly, sea lettuce lacks many of the

Oxygen and other useful substances diffuse into cells and waste products diffuse out of cells.



systems found in land plants. Most of the substances it needs to survive diffuse from the water into the cells of the sea lettuce and waste products diffuse out of the cells into the water.

8.2.2 Multicellular organisms

For larger animals with many layers of cells, things are not so simple. Many of their cells are deep inside their bodies and not in direct contact with their surroundings. How do oxygen and nutrients get to these cells? How do these cells get rid of their waste products and where does the waste go?

Most multicellular organisms are very complex and contain a number of systems that keep them alive.

- The respiratory system takes in oxygen and gets rid of carbon dioxide.
- The digestive system breaks down food into particles that are small enough to pass through the walls of the intestines and into the bloodstream.
- The circulatory system carries these nutrients, as well as oxygen, to all cells in the body. It also carries waste away from cells and takes it to organs that can excrete (get rid of) this waste.
- The nervous system carries and processes messages along nerves from one part of the body to another.
- The skeletal system enables the body to move. Some bones also protect important organs.

Systems consist of organs. Some of the organs of the digestive system are the stomach, oesophagus, pancreas, intestines and liver. Organs of the circulatory system include the heart and blood vessels. Organs are made up of different types of tissue. The heart contains cardiac muscle tissue, blood, connective tissue and adipose tissue (fat). Tissues, in turn, are made of cells. Adipose tissue is made up of cells that store fat. Cardiac muscle tissue consists of cardiac muscle cells.

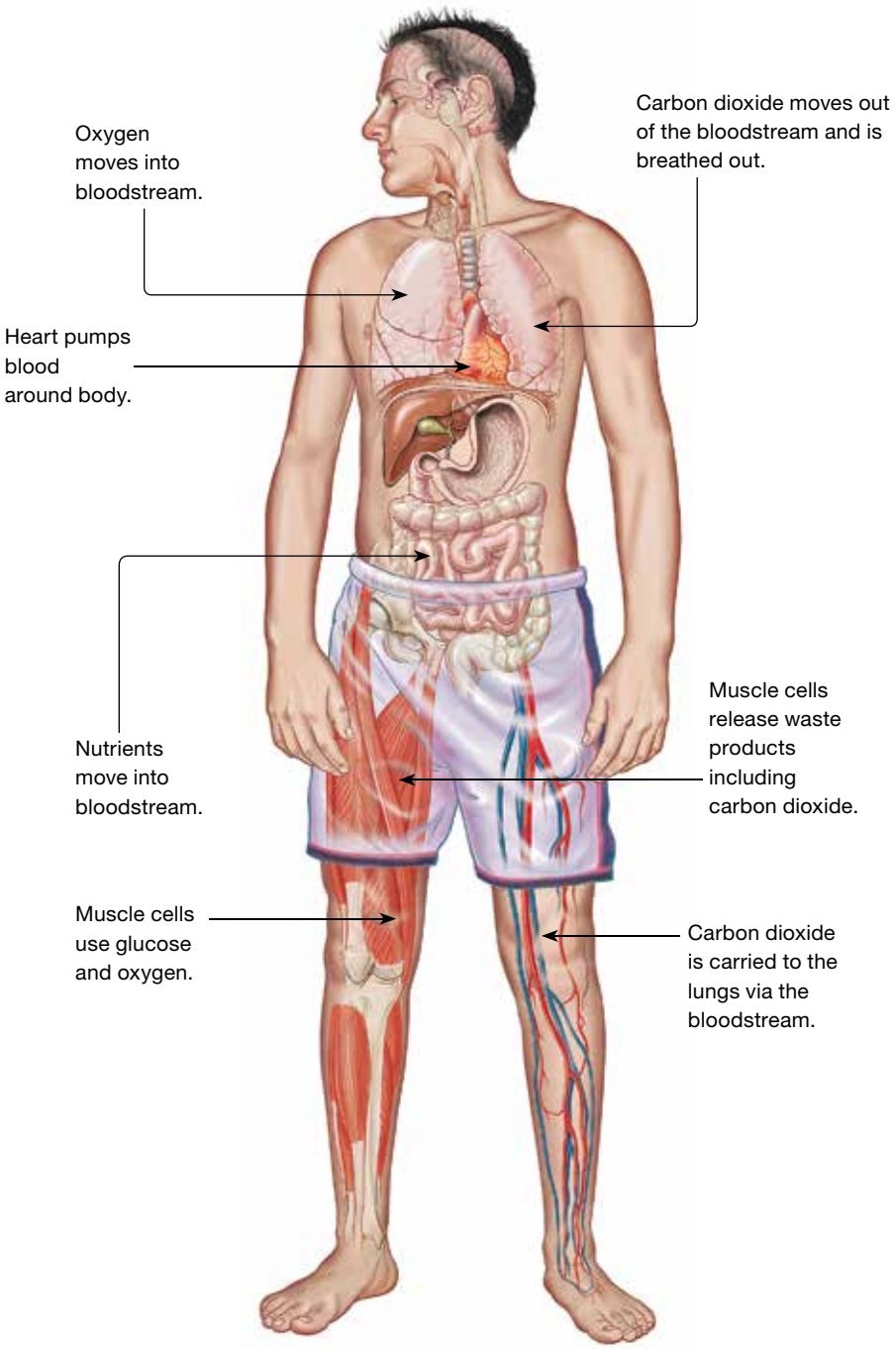
A flatworm (left) and sea lettuce (right) are examples of multicellular organisms that are very thin and so do not require many systems to keep them alive.



8.2.3 Working together

Body systems work together to keep organisms alive. The respiratory system brings oxygen into the lungs, but it is the circulatory system that delivers the oxygen to all cells. Without these two systems working together, cells would not obtain the oxygen they need for respiration. Similarly, while the digestive system breaks down food, once the nutrients in food have been converted to particles that are small enough to enter the bloodstream, these also must be transported to cells via the circulatory system. To move our limbs, muscles need to receive signals from the nervous system. Hormones produced by the endocrine system play an important role in regulating the action of the kidneys, which are part of the excretory system. The body systems must act as members of a team; each has a specific task but they must work collaboratively to keep the body functioning.

All body systems work together.



Some organs in our body systems

System	Organs
Reproductive	Ovaries, testes
Musculoskeletal	Muscles, skeleton
Nervous	Brain, nerves
Excretory	Kidney, ureter
Respiratory	Trachea, lungs
Circulatory	Heart, arteries
Digestive	Stomach, liver

INVESTIGATION 8.2

The pluck

AIM: To investigate the structures of some internal organs of a sheep

You will need:

sheep's pluck (heart and lungs) with part of the liver and trachea attached
newspaper and tray to place the pluck on
plastic disposable gloves
balloon pump or vacuum cleaner

- Carefully observe the sheep's heart, lungs, liver and trachea.
- Push a piece of rubber tubing into the trachea until it reaches one of the lungs. Using a balloon pump or a vacuum cleaner in reverse mode, blow some air into the trachea.

CAUTION: For hygiene reasons, it is not recommended that you use your mouth to blow air into the tube inserted in the trachea.

- Cut off a small piece of lung, liver and heart. Place each in a beaker full of water. Which one floats? Why?
- You might have heard of people having a 'burst lung'. That seems to suggest that lungs are hollow, like balloons. Slice through one of the lungs to find out if it really is hollow.
- Cut through the heart and liver to find out if they are hollow.

Discussion

1. Copy and complete the table below in your notebook.

Organ	Shape (sketch)	Approx. size	Colour	System to which this organ belongs
Liver				
Lung				
Heart				
Trachea				

2. Which major blood vessels can be seen?
3. What happens to the lungs when air is blown in?
4. Explain why there are rings of cartilage around the trachea.
5. Where does the air go when the lungs blow up?
6. Why does the heart need to be hollow?
7. Use reference books to find out the function of the liver.

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. **Outline** how unicellular organisms take in oxygen and nutrients.
2. Copy and complete the following statements.
   (a) _____ are made up of groups of cells that carry out a specialised job.
   (b) _____ are made up of different types of tissues.
   (c) Organs work together to make up a _____.
   (d) The _____ in an organism work together to keep it alive.

Think and reason

3. **Classify** each of the following as a type of cell (C), tissue (T), organ (O) or system: eye, smooth muscle, cardiac muscle, heart, white blood cell, liver, skin, skin cells, brain, neuron (nerve cell), circulatory system, intestine.

4. The table below is jumbled up. Re-organise the information in the table.

System	Some organs in this system	Function
Digestive	Brain, spinal cord, nerves	Takes oxygen into the body and removes carbon dioxide from the body
Musculoskeletal	Lymph nodes (also involves white blood cells in blood)	Coordinates processes in the body by sending messages that travel through nerves
Respiratory	Lungs, trachea	Carries oxygen and nutrients to all cells in the body; carries waste away from cells
Endocrine	Ovaries, uterus, fallopian tubes (female) Penis, testes, vas deferens (male)	Protects the body from disease
Nervous	Glands (e.g. thyroid gland, adrenal gland)	Breaks down food into particles that are small enough to pass through the walls of the intestine into the bloodstream
Circulatory	Bones, ligaments	Is involved in reproduction (making babies)
Reproductive	Stomach, intestine, oesophagus, pancreas, liver	Coordinates processes in the body by releasing hormones into the bloodstream
Immune	Heart, blood vessels	Supports the body, protects organs such as the heart and brain and enables movement

5. **Identify** which body system has each of the following functions.
   (a) Detecting stimuli
   (b) Supporting and moving the body
   (c) Taking in oxygen and getting rid of carbon dioxide
   (d) Conducting messages from one part of the body to another
6. In 2010, a male patient was the first person to be given an intestine transplant in Australia (previously the procedure had been carried out only overseas). Before the transplant he was not able to eat and had to receive nutrients through a drip. **Explain** how the drip was keeping him alive.

Investigate

7. Do all animals have the same body systems as humans? Choose one animal from the following list and investigate whether it has all the body systems shown in the mind map.

   dog snake spider worm starfish jellyfish

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Complete this digital doc: Worksheet 8.1: Organ systems (doc-12407)

Watch this eLesson: Leonardo's sketches and anatomy (eles-1769)

8.3 Taking in nutrients

8.3.1 Food contains energy

The human body, just like a car, needs to be provided with fuel to keep it working. That fuel is the food we eat. Our bodies break down the food and release the energy that is locked up inside it. This energy can then be used by our bodies to move, grow and carry out important processes that are vital to our health.

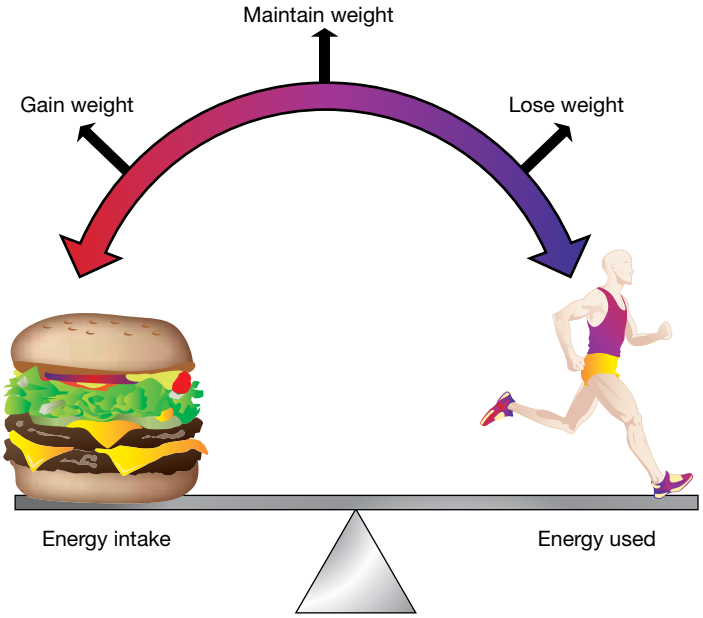
Food provides more than just energy though; it also provides important nutrients, vitamins and minerals that are essential to keep the body functioning. The digestive system breaks down the food we eat so that nutrients can enter the bloodstream and be delivered to cells.

Food contains stored energy. The amount of energy stored in the food is measured in kilojoules (kJ) or Calories.

The amount of energy needed each day depends on how much physical activity a person does, as well as other factors including their size, age and gender. The table below shows the amount of energy used by a range of activities. For example, a person who sits at a desk for most of the day needs to eat less food than a person who spends a large part of the day walking. If we take in more energy than we need, our bodies store the excess energy as fat. If we take in less energy than we need, some of this fat can be broken down and used for energy.

Activity	Approximate energy use (kJ) per hour
Sleeping	250
Very light — sitting, reading, watching television, driving	450
Light — walking leisurely, washing, shopping, light sport such as golf	950
Moderate — fast walking, heavy gardening, moderate sport such as bicycling, tennis, dancing	1800
Heavy — vigorous work, sport such as swimming, running, basketball and football	3500

To maintain a healthy weight, it is important to balance your energy intake with the energy you use.



HOW ABOUT THAT!

It seems so simple doesn't it? Take in more energy than your body uses up and you will put on weight. Take in less energy than your body uses up and you will lose weight. Yet some people seem to be able to eat a high-energy diet with little effect on their weight.



One scientist set out to determine whether eating too much food has the same effect on all people. Fredrick Nyström of Linköping University in Sweden recruited 18 lean and healthy volunteers and asked them to double their energy intake and avoid exercising for one month. For health reasons, the volunteers were asked to stop the experiment if their weight increased by more than 15 per cent of their original weight. One volunteer reached this after just two weeks. Another volunteer found that his weight had increased by only 4.6 kg by the end of the experiment.

Nyström has suggested that perhaps some people release more of the extra energy they take in as heat rather than store it as fat. So, after overeating, these people may feel warmer or more fidgety as their bodies use up some of the extra energy.

Eating energy-dense food caused all of the volunteers to gain weight, but some gained weight a lot faster than others.

INVESTIGATION 8.3

Measuring the energy in food

AIM: To compare the amounts of energy stored in a range of foods

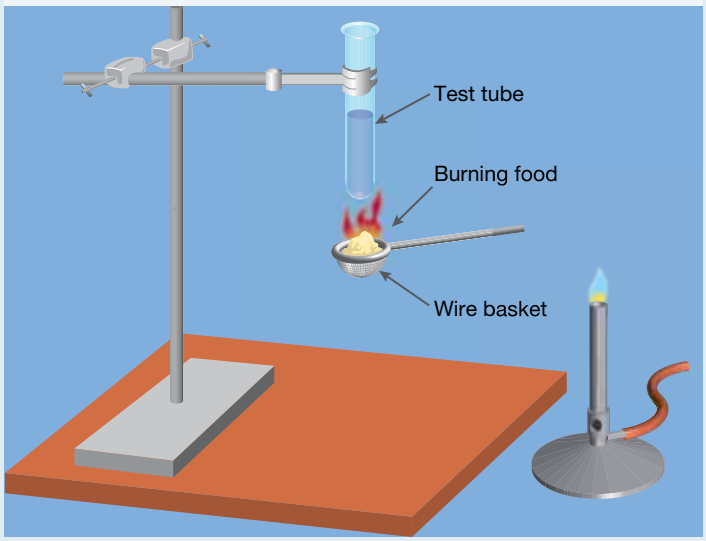
You will need:

small metal basket (used to fry food)
samples of small biscuits, potato chips, uncooked pasta, crouton or small piece of toast
thermometer
retort stand, bosshead and clamp
large test tube
Bunsen burner
measuring cylinder

Before starting this experiment, read all the following steps and make a list of the risks (dangers) associated with this activity and how you plan to minimise these risks.

- Use the clamp to attach the test tube to the retort stand.
- Measure 30 mL of water and pour it into the test tube.
- Measure the temperature of the water.
- Weigh the biscuit.
- Place the small biscuit in the wire basket and set fire to it using the Bunsen burner. When the biscuit is alight, put the basket containing the biscuit underneath the test tube. The heat released from the burning biscuit will heat the water. Hold the basket under the test tube until the biscuit is completely burned. You can tell that the biscuit is completely burned if it is all black and will not re-ignite in the Bunsen burner flame.
- Measure the temperature of the water again.
- Calculate the amount of energy that was stored in the biscuit, using the following equation.

The apparatus used in this experiment



$$\text{Energy (in joules)} = 4.2 \times \text{volume of water (in mL)} \times \text{increase in temperature (in °C)}$$

- Calculate the amount of energy per gram of food by dividing the amount of energy by the mass of the food.
- Repeat the steps above using the other food samples.
- Copy and complete the table below.

Food	Biscuit	Chip	Pasta	Crouton/ toast
a. Mass of food (g)				
b. Volume of water (mL)				
c. Initial temperature of water (°C)				
d. Final temperature of water (°C)				
e. Increase in temperature (= *d* − *c*)				
f. Energy in food (J) (= 4.2 × 30 × *e*)				
g. Energy in food (kJ) (= *f* ÷ 1000)				
h. Energy per gram of food (kJ/g) (= *g* ÷ *a*)				

Discussion

1. Copy and complete the aim of this experiment: 'To compare the amounts of _____ stored in a range of foods'.
2. Copy and complete the conclusion: 'The food that contained the most energy per gram was _____'.
3. Why was it necessary to calculate the amount of energy per gram of food?
4. Did all the heat from the burning food go into heating the water? Explain how this might have affected the validity of this experiment.

8.3.2 What is in the food we eat?

The food we eat contains five main nutrient groups: carbohydrates, proteins, lipids, vitamins and minerals.

Nutrient groups

Nutrient group	Chemistry	Role	Foods with high levels of this nutrient	Energy per gram (kJ)
Carbohydrates	Simple carbohydrates are also called sugars (e.g. sucrose, glucose). Complex carbohydrates are made up of simple sugars linked together (e.g. starch consists of glucose units linked together).	Source of energy. *Note:* The energy from complex carbohydrates is released more slowly, so these tend to be a better source of energy.	Simple carbohydrates: soft drinks, lollies, fruit Complex carbohydrates: pasta, rice, cereal	16
Proteins	Amino acids linked together	Source of energy; used to make enzymes and body tissues (including muscle)	Meat, fish, dairy products, legumes	17
Lipids (fats and oils)	Fatty acids attached to glycerol	Source of energy; source of essential fatty acids	Nuts, butter, cooking oil, biscuits, chips	37
Vitamins	Varies	Needed for particular chemical processes in the body	Fat-soluble vitamins: foods containing fats and oils (including fatty fish such as salmon) Water-soluble vitamins: fruit, vegetables, grains	0
Minerals (e.g. calcium, magnesium, iron, zinc)	Varies	Needed for particular chemical processes in the body	Various (e.g. red meat is high in iron)	0

HOW ABOUT THAT!

In your great-grandparents' days, many children were given a daily dose of cod liver oil to maintain good health. It turns out that your great-grandparents may have been right about the benefits of fish oil. Fish oil is rich in omega-3 fatty acids. These fatty acids are being investigated as a possible treatment for conditions including rheumatoid arthritis, depression, attention deficit disorder and heart disease.

A number of scientific studies have shown that omega-3 fatty acids affect behaviour and mood. For example, Bernard Gesch did an experiment involving British prison inmates. He gave half the people who had volunteered for his study a daily supplement that contained omega-3 fatty acids and other vitamins and minerals. The other prisoners were given a placebo (a tablet that looked just like the supplement but did not contain fatty acids, vitamins or minerals). Over time, he found that the prisoners taking the supplement were involved in a lot fewer violent incidents. The prisoners taking the placebo showed no significant change in their behaviour.

Some sources of omega-3 fatty acids



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** which unit energy is usually measured in.
2. If you take in more energy than your body needs, **explain** what happens to the extra energy.
3. **Explain** why it is important to use a placebo when testing the effect of a dietary supplement or medicine.
4. Match each term in the left-hand column with a definition from the right-hand column.

Term	Definition
a. Glucose	A A source of protein
b. Protein	B Simple sugars linked together
c. Lipids	C A component of lipids
d. Pasta	D Amino acids linked together
e. Glycerol	E Fats and oil
f. Complex carbohydrates	F Example of simple carbohydrate
g. Fish	G A source of carbohydrate

5. **Identify** what the items in the following pairs have in common.
   (a) Carbohydrates and lipids
   (b) Glucose and starch
   (c) Fats and oils
   (d) Iron and Zinc
6. In his experiment (see How about that!), Bernard Gesch used a supplement that contained both fatty acids and other minerals and vitamins. **Outline** how he could test whether it was the fatty acids or the vitamins and minerals that caused the improvement in the behaviour of the prisoners.

Skill builder

7. Use the table on page 295 to answer the following questions.
   (a) How much energy is used up in 1 hour of fast walking?
   (b) **Calculate** the amount of energy used in 30 minutes of running.
   (c) **Explain** why two people might both dance for 20 minutes but burn very different amounts of energy.

8. The tables below show the recommended daily energy intake for 12–15 year olds and the amount of energy contained in a range of foods sold at a snack bar.

Recommended daily energy intake, in kilojoules, for 12–15 year olds

Age (years)	Recommended daily intake (kJ) Male	Female
12	9800	8600
13	10400	9000
14	11200	9200
15	11800	9300

Nutritional information for a snack bar menu

Food	Energy (kJ)
Pizza (2 slices)	2060
Hamburger	1900
Salad sandwich	940
Chocolate eclair	1320
Fresh fruit salad	290
Apple pie with ice-cream	2310
Medium cola	384
Strawberry thick shake	1230
Medium orange juice	530

(a) What is the recommended daily energy intake for someone of your age and gender?
(b) For lunch, Fred ate one hamburger and an apple pie with ice-cream. He also drank one medium orange juice.
(i) **Calculate** Fred's energy intake.
(ii) Fred is 13. **Calculate** the percentage of his recommended daily energy intake that his lunch contains.
(c) **Identify** the combination of main course and dessert that supplies the least energy.
(d) **Calculate** how many minutes of walking would be needed to use up the energy contained in two slices of pizza. (*Hint:* See the Food contains energy table.)

Use data

9. Use the nutritional panel below to answer these questions.
(a) The recommended daily intake of protein for a 13 year old is 40 g. **Calculate** the percentage of the recommended daily intake of protein supplied by one serving of this food.
(b) If one serving of this food provides 6 per cent of the recommended daily intake of fat, **calculate** the daily recommended intake of fat.
(c) Which food could this label belong to?

NUTRITIONAL INFORMATION Servings per package: 8 Serving size: 30 g	Average quantity per serving	Average quantity per 100 g
Energy	470 kJ	1570 kJ
Protein	1.4 g	4.6 g
Fat – total – saturated	2.8 g 2.0 g	9.3 g 6.7 g
Carbohydrate – sugars	21.0 g 8.7 g	70.0 g 28.9 g
Dietary fibre	1.7 g	5.5 g
Sodium	50 mg	180 mg

Investigate

10. Collect 10 nutrition panels from food packages. Use the information on the nutrition panels to rank the foods from highest to lowest for:
(a) energy (b) fat (c) carbohydrate (d) protein.
11. Some foods are labelled with the Heart Foundation Tick. Find out what requirements the food must meet to be allowed to display the tick.

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Complete this digital doc: Worksheet 8.2: Nutrients (doc-12408)
Complete this digital doc: Worksheet 8.3: Food facts (doc-12409)

8.4 The digestive system

8.4.1 Digesting the food

The role of the digestive system is to break down the food that we eat into particles that are small enough to pass through the walls of the intestines and into our blood. In this way, the nutrients in food can reach our body's cells. A number of organs make up the digestive system. Some organs break up the food mechanically by cutting, grinding or churning it. Other organs secrete chemicals that can break the chemicals in the food into smaller molecules.

Tongue
Works the food into a little round ball, called a **bolus**. It then pushes the ball to the back of the mouth, where it is swallowed.

Teeth
Used to bite and chew food into small pieces

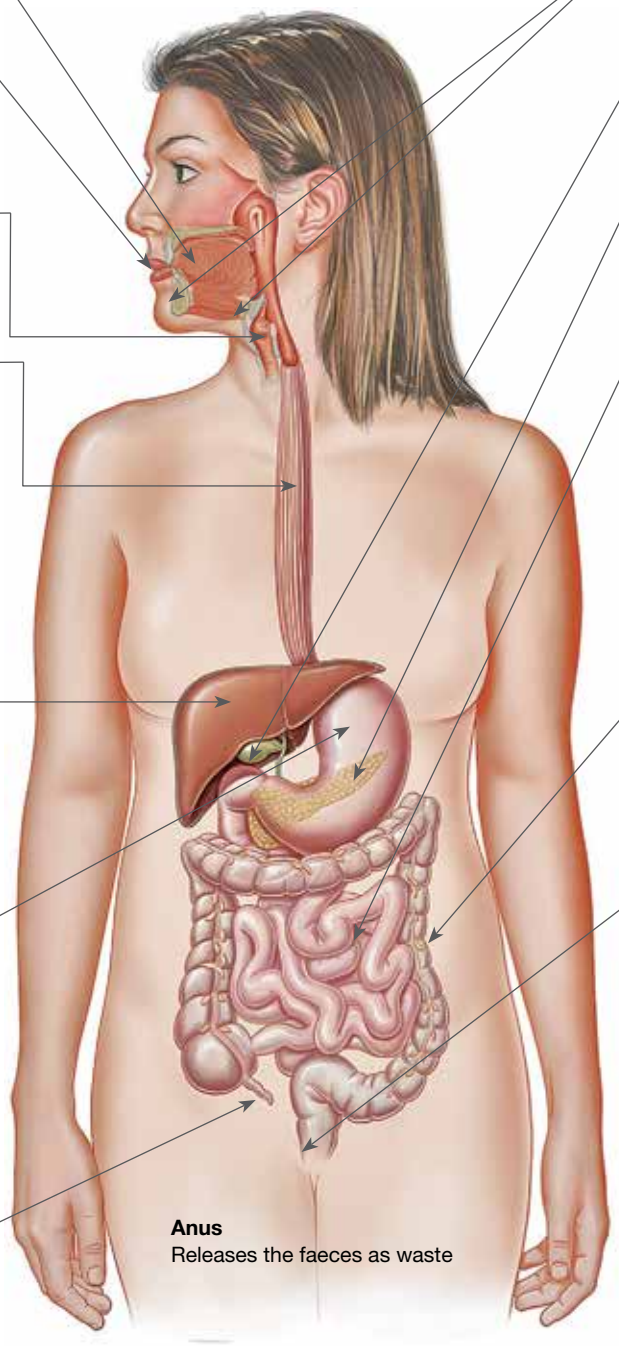
Epiglottis
A flap of tissue that closes off the entry to your lungs so that food does not go down and cause you to choke

Oesophagus
Directs the food to the stomach. It is a long muscular tube that moves food by the process of **peristalsis**. Peristalsis squeezes food down the oesophagus by repeated waves of muscle contractions.

Liver
Controls the number of glucose molecules in the blood. When there is too much, the liver stores it as glycogen and releases it when needed. It also makes **bile**, which breaks down fat into small droplets in the small intestine. The bile is stored by the gall bladder until it is needed in the small intestine. The liver also breaks down toxins in the blood.

Stomach
A large muscular organ that churns and mixes the food. The stomach lining releases chemicals that start to break down protein. It also releases hydrochloric acid, which kills unwanted bacteria. The stomach can hold between two and four litres of food and can store it for about four hours.

Appendix
A small projection at the beginning of the large intestine. In humans, it does not help with digestion.



Anus
Releases the faeces as waste

Salivary glands
Make about 1.5 L of **saliva** a day. Saliva moistens the food, making it easier to chew and swallow. Saliva also contains chemicals that break down the **starch** in food.

Gall bladder
Stores bile made in the liver until needed in the small intestine

Pancreas
Makes chemicals that are used in the small intestine. It also reduces the effect of the acid from the stomach on the walls of the small intestine.

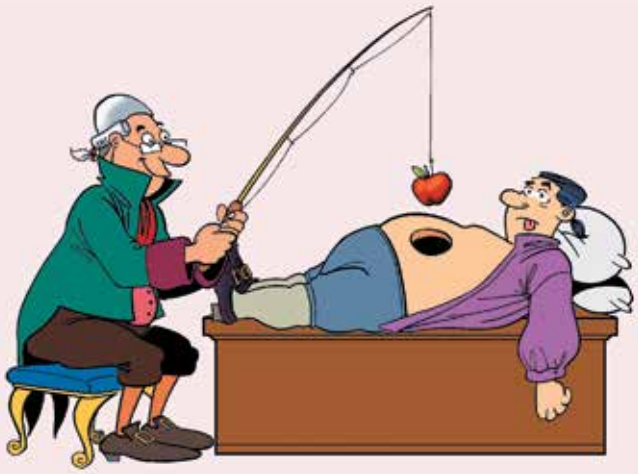
Small intestine
A long, hollow, coiled tube about six metres long. It is the main organ of digestion. Food, which is now like a creamy soup, passes slowly into it. Liquid from the pancreas and bile from the gall bladder enter the small intestine to help with digestion. The small intestine is where the breakdown of starch and protein is finished and fat breakdown occurs. The food particles are then tiny and can pass through the wall of the small intestine into the bloodstream.

Large intestine
Undigested food and water pass into the large intestine from the small intestine. Bacteria in the large intestine help in making some vitamins and are the main source of gas. Water, vitamins and minerals pass into the bloodstream.

Rectum
Faeces is stored in this last part of the large intestine. Faeces contains the waste products of digestion. It consists of about 75 per cent water and 25 per cent solid matter — mainly dead bacteria and fibre.

HOW ABOUT THAT!

When Alexis St Martin was accidentally shot in the stomach at close range, he was not expected to recover from his injuries. He had a hole the size of a fist in his stomach. An army surgeon named Beaumont treated him. Alexis did recover but, as the wound healed itself, the edge of the hole in his stomach attached itself to the edge of the hole in his skin, so there was a small passage between the inside of his stomach and the outside of his body. The passage had to be sealed with bandages so the food and stomach juices could not leak out of his stomach.

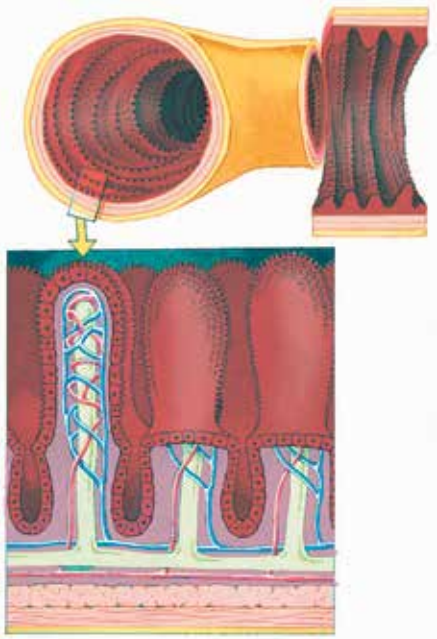


Beaumont used this opportunity to study the process of digestion. Alexis became Beaumont's servant. As well as doing all the tasks normally expected of a servant, Alexis was also involved in a number of experiments on digestion. Beaumont collected some of the fluid that emerged from the hole in Alexis' stomach and did tests on it. He could also dangle various foods by a string into Alexis's stomach and pull them out after a period of time to find out what had happened to the food in the stomach.

8.4.2 Zooming in on the small intestine

Nutrients must pass through the walls of the small intestine and into the bloodstream. The walls of the small intestine are not smooth; they are lined with small finger-like projections called villi. This increases the surface area through which nutrients can diffuse across the walls of the small intestine. There are also many small blood vessels called capillaries associated with the villi. These transport the nutrients away from the intestines.

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



8.4.3 Coeliac disease

Coeliac disease is a condition where the villi of the small intestine are damaged. People with coeliac disease are intolerant to gluten, a substance found in wheat, oats, barley and rye and the numerous food additives made from these. If they eat foods containing gluten, the villi in their small intestines become damaged over time. This means that they can no longer absorb certain nutrients properly. An early symptom of coeliac disease is anaemia (low blood iron levels) as iron absorption is reduced by the damaged villi. Some coeliac sufferers may also experience stomach pains and bloating after eating foods containing gluten.

It is possible for coeliac disease to develop in childhood, but many people do not develop it until their thirties or later. Scientists are not sure why. Perhaps certain triggers are needed for the disease to develop. If coeliac disease is diagnosed in its early stages, it is reversible provided that the person completely avoids gluten for the rest of their life. This is challenging as gluten is found in so many foods including most types of bread, pasta, cakes and biscuits. Failure to avoid gluten can have dire consequences for people with coeliac disease. Apart from feeling unwell and being deficient in certain nutrients, coeliac sufferers who do not follow a gluten-free diet also have an increased risk of developing bowel cancer.

Biopsies of (a) normal and (b) coeliac intestine



Australian researchers are attempting to develop a vaccine as a new treatment for coeliac disease. In 2009, Dr Robert Anderson and his team at the Walter and Eliza Hall Institute of Medical Research in Melbourne began the world's first trials of a coeliac vaccine. If this treatment is successful, it could mean the end of gluten-free diets for people with the condition.

Dr Robert Anderson and his team at the Walter and Eliza Hall Institute of Medical Research in Melbourne began the world's first trials of a coeliac vaccine.



INVESTIGATION 8.4

Observing villi

AIM: To investigate the structure of the walls of the small intestine

You will need:

prepared slides of walls of the small intestine
microscope
photos of villi seen in the weblinks in the Resources tab

- Observe the prepared slide under the microscope.
- Draw a diagram showing a small section of the walls of the intestine. Label a villus.
- Compare your diagram with the photos in the Resources tab.

Discussion

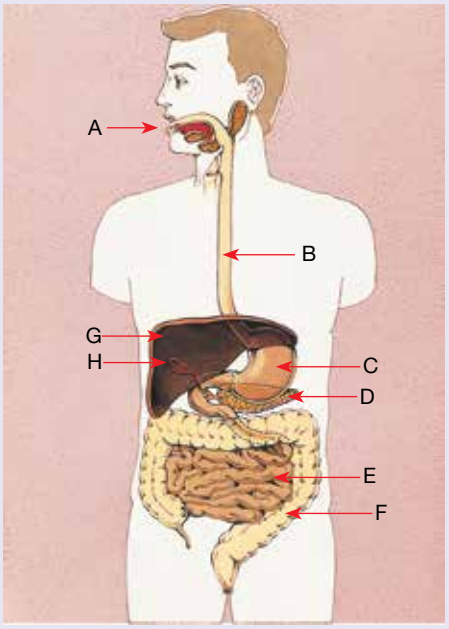
1. Describe the appearance of the walls of the intestines.
2. Look carefully at one of the villi. Does it have a smooth shape?
3. Compare the two photos found by following the **Observing villi** weblinks in the Resources tab. Which of the photos shows the appearance of the villi under a light microscope? Which photo is an electron micrograph? Justify your answer. (*Hint:* See page 302.)

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. Match the following terms with their descriptions
   Terms: oesophagus, gall bladder, liver, digestion, stomach, small intestine, epiglottis, rectum, peristalsis
   Descriptions:
   (a) The breakdown of food into particles that are small enough to pass through the walls of the intestines
   (b) The tube that joins the mouth to the stomach
   (c) Muscular contractions that move food along the digestive tract
   (d) A flap of tissue that blocks the entry to the lungs when you swallow
   (e) The organ that produces bile
   (f) The organ where the digestion of protein begins
   (g) The place where bile is stored
   (h) Where fat is broken down
   (i) Where faeces are stored until they can be released
2. Copy the table below and fill it in for each of the organs labelled in the diagram at the right.



Organ	Function

Think

3. Beaumont's experiments on Alexis St Martin raise some ethical issues.
   (a) What does the term 'ethical' mean?
   (b) Why would Beaumont's experiments be seen as unethical by some people?
   (c) Do you think Beaumont would be allowed to carry out such experiments today? Give a reason for your answer.
4. **Explain** why a person who has coeliac disease is more likely to be anaemic (have low iron levels) or suffer from osteoporosis (a condition resulting from calcium deficiency).

Research

5. **Design** a three-course gluten-free meal. Make sure you check the list of ingredients for all foods included in your menu.
6. Test your knowledge of the digestive system by completing the **Digestive jigsaw** interactivity in the Resources tab.

7. Find out more about the digestion of particular types of food by using the **Digestion animation** weblink in the Resources tab.
8. Practise naming the parts of the digestive system by using the **Digestive system drag-and-drop** weblink in the Resources tab.

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- **Complete this digital doc:** Worksheet 8.4: The digestive system (doc-12410)
- **Watch this eLesson:** From dinner plate to sewerage system (eles-0056)
- **Try out this interactivity:** Digestive jigsaw (int-0216)
- **Explore more with this weblink:** Observing villi 1
- **Explore more with this weblink:** Observing villi 2
- **Explore more with this weblink:** Digestion animation
- **Explore more with this weblink:** Digestive system drag-and-drop

8.5 Physical or chemical digestion?

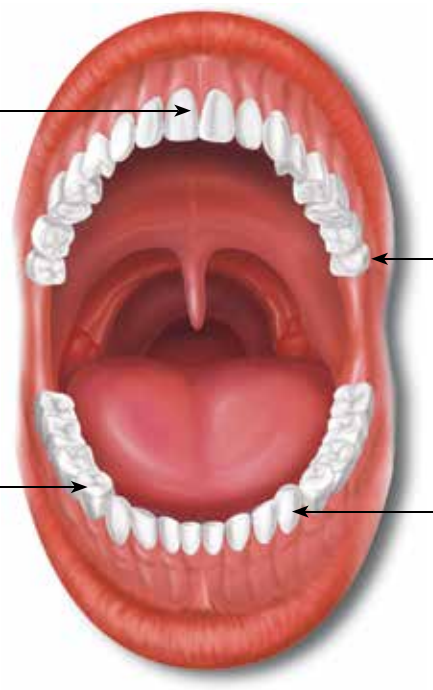
8.5.1 Let's get physical!

Digestion involves both physical and chemical processes. When food is broken down physically, it is cut, ground or churned to make the particles of food smaller. This increases the surface area of the food. Substances called enzymes can then work on the food more effectively to chemically break down the large molecules in the food so that they are small enough to pass into the bloodstream and be transported around the body.

Physical digestion mainly involves the teeth, although the churning action of the stomach is also an example of physical digestion. Humans have four different types of teeth. Each type has a different shape, position in the mouth and job in breaking down food.

Incisor
Incisors are spade shaped. They have a straight, sharp edge for cutting and biting food. You have eight incisors in total — four on each of the upper and lower jaws at the front of the mouth.

Premolar
Premolars roll and crush food. There are eight premolars — two next to each **canine**. They have two pointed cusps to help break down food.



Molar
You have between eight and twelve **molars**, depending on your age. The last four molars are known as your wisdom teeth; they usually appear at the age of 17 or older. Molars grind food. They have between three and five **cusps**. The rough cusps help to break down the food.

Canine
There are four pointed canines — one on each side of the incisors. They are used for shearing and tearing through tough food.

8.5.2 Chemical breakdown

Once the food has been broken down into small pieces, chemicals called enzymes can get to work on the food particles. Enzymes speed up the chemical reactions in the body. There are many types of enzymes. Those involved in digestion break down the complex chemicals found in food into small molecules that can pass through the walls of the small intestine and into the bloodstream.

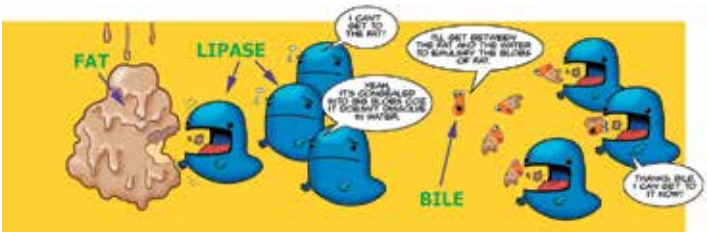
8.5.3 Fat stuff

Breaking down lipids, such as fats and oils, is hard work! Because lipids are insoluble in water, they tend to clump together into large blobs. A substance called bile helps solve this problem. Bile is produced by your liver and stored in your gall bladder. As half of the bile molecule is attracted to water and the other half is attracted to lipids, it helps to **emulsify** or separate the lipids so the lipase enzymes can gain access to them and do their job. This is an *example of mechanical* digestion (bile) and chemical digestion (lipase) working together to get the job done!

Some enzymes involved in digestion

Enzyme	Organ that secretes the enzyme	Role of enzyme
Amylase	Salivary glands in mouth	Break down starch into simple sugars such as glucose
Pepsin and trypsin	Stomach. These and other protease (protein-digesting) enzymes are produced in the stomach, pancreas and intestine.	Break down proteins into amino acids
Lipase	Pancreas	Break down fats and oils into fatty acids and glycerol; occurs mainly in the small intestine

Bile emulsifies fat so that lipases can break it down.



INVESTIGATION 8.5

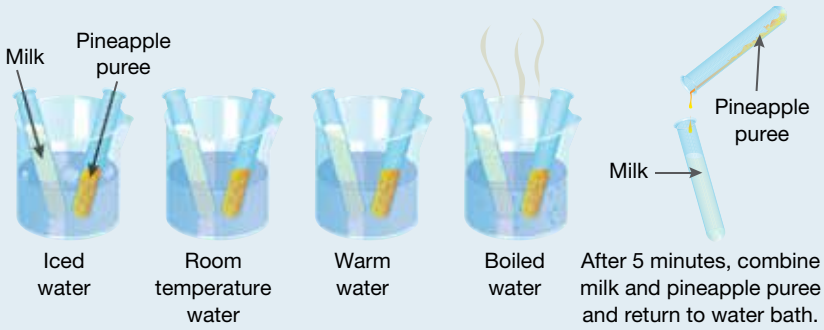
Does temperature affect enzymes?

AIM: To investigate how enzyme activity is affected by temperature

You will need:

4 beakers
milk
8 test tubes
4 thermometers
fresh pineapple puree (Fresh pineapple can be pureed using a food processor. If fresh pineapple is not available, use junket powder or a junket tablet dissolved in 10 mL water.)

- Add water to the beakers so that they are two-thirds full. Use cold tap water and ice for beaker 1, cold tap water for beaker 2, hot tap water for beaker 3 and boiling water (from a kettle) for beaker 4. These are the 'water baths'.
- Half-fill four test tubes with milk and put one test tube in each water bath.
- Pour one teaspoon of fresh pineapple puree (or 1 mL junket solution) into each of the other four test tubes. Put one of these test tubes in each water bath.
- Allow the test tubes to stand in the water baths for at least 5 minutes.
- For each water bath, pour the fresh pineapple puree into the milk and stir briefly. Quickly record the temperature of the milk and pineapple mixture and then allow it to stand undisturbed. The mixture will eventually set. Record the time taken to set. If the milk has not set after 15 minutes, record the time as 15+.



- Copy and complete the table of results on the right.

Temperature of milk and pineapple mixture (°C)	Time taken to set (min)

Discussion

1. Pineapple juice and junket contain an enzyme that causes a protein in milk (casein) to undergo a chemical reaction and change texture; that is why the milk sets. At what temperature did the enzyme work best? Explain your answer.
2. Did the enzyme work well at very high temperatures? Explain your answer.
3. Which variables were controlled in this experiment?
4. Do you think that the same results would be obtained if tinned pineapple puree was used instead of fresh pineapple? Explain your answer.

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. **Distinguish** between physical and chemical digestion.
2. **Identify** the four types of teeth and their functions.
3. **Explain** why it is important to break food down into small pieces.
4. **Describe** the function of enzymes.
5. **Identify** the main digestive enzymes, where they are made and the type of substance they break down.
6. **Describe** how bile helps lipase enzymes get their work done.

Think

7. When you eat a piece of bread, nothing much can be tasted at first. As you continue to chew, a sweet taste can be detected. **Explain** why.
8. It is sometimes necessary, for medical reasons, to remove the gall bladder. The gall bladder stores bile. **Justify** why a person who has had their gall bladder removed might need to follow a low-fat diet.
9. Amylase breaks starch down into glucose. Iodine solution turns blue-black when it is added to starch, but it is a light brown colour when starch is not present.
   (a) Jossie combined 10 mL of starch solution with 1 mL of amylase solution. She removed a small amount of the mixture and added iodine solution. The iodine solution turned blue-black. Half an hour later, Jossie removed another small amount of the mixture and tested it with iodine solution. This time the iodine remained light brown. **Explain** Jossie's observation.
   (b) Design an experiment to test the hypothesis that amylase is more active (converts starch to glucose faster) at 50°C than at 20°C.

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Complete this digital doc: Worksheet 8.5: Mechanical and chemical digestion (doc-12411)

8.6 Dietary deficiencies — one problem, many opinions

Science as a human endeavour

8.6.1 Tackling childhood obesity

Australia has one of highest rates of obesity worldwide, yet many Australians suffer from a range of illnesses that are linked to dietary deficiencies. Healthy food is readily available to most Australians, but many of us make poor choices when it comes to our diet. What is the best approach to tackle this issue? Opinions are divided.

The rate of obesity in children has risen dramatically over recent times. A recent survey showed that one in four children aged 5–17 years are overweight or obese. Health professionals are concerned about this because children who are overweight are at higher risk of a range of medical conditions including problems with joints, high blood pressure and type 2 diabetes. Many children who are obese go on to become overweight adults and may later develop health conditions associated with adult obesity.

The reasons for increasing rates of childhood obesity include:

- eating too much food that is high in kilojoules but lacking in vitamins, minerals and other important nutrients
- not getting enough physical activity. Many children now spend a great deal of their spare time on sedentary activities such as watching TV and playing computer games rather than running around. Children are increasingly driven everywhere and devices such as lifts, escalators and remote controls have reduced the energy we expend each day.

Opinions vary on the best way to deal with childhood obesity, particularly in very young children who have only limited choice in the food they eat, since their parents prepare their meals. Below are some strategies that have been proposed.

- Banning television advertising for unhealthy food during children's programs
- Applying a tax to foods that are high in fat or sugar
- Limiting the size of soft drinks in fast food outlets and restaurants
- Using a traffic light labelling system on foods (a green light for the healthiest foods, an amber light for foods that are not quite as healthy and a red light for foods that should be eaten only occasionally)
- Regulating the type of food that can be sold by school canteens (This is already in place in many NSW schools.)
- Increasing the number of hours spent doing physical activity in schools
- Allocating more time to teach children about nutrition and healthy meal preparation at school

Which of these approaches is likely to be most effective?

The treatment of type 1 diabetes usually involves insulin injections or the use of an insulin pump.



8.6.2 Type 2 diabetes

Diabetes mellitus is a group of diseases that affect the way your body uses blood sugar (glucose). There are different forms of diabetes. Type 1 diabetes usually starts in childhood and type 2 diabetes usually starts later in life.

Usually, glucose is able to enter your cells because of the action of insulin. Insulin is made in the pancreas. If you have diabetes, glucose cannot get into your cells. It

stays in your blood. This happens either because your body does not make enough insulin, or because your cells do not allow glucose to enter. If the pancreas does not make enough insulin, it may be necessary to have insulin injections or use an insulin pump. Too much glucose in your blood can damage almost every major organ in your body. This can be fatal.

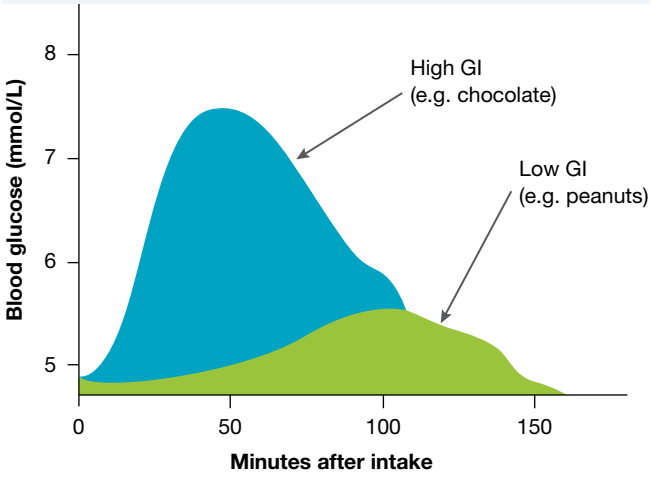
Type I diabetes is not linked to obesity. The exact cause of type I diabetes is unknown, but this type of diabetes is just as likely to affect a child in the healthy weight range as an overweight child. However, there is a link between type II diabetes and obesity. A combination of factors determine a person's chance of getting type II diabetes, including hereditary factors, but diet and other lifestyle factors are important. By eating a balanced diet, having a healthy weight and getting lots of exercise, you can reduce your chance of getting adult-onset diabetes, even if there is a high incidence of the disease in your family.

8.6.3 High or low GI?

You might have noticed that some foods are labelled as 'low GI'. The GI or glycaemic index of a food is a measure of the time it takes for your blood sugar level to rise after you eat that food. Foods that are high in sugar, and starchy foods that are low in fibre, can be digested quickly by amylase. These foods have a high GI and they provide only a short burst of glucose. As your blood glucose level drops, you may start to feel hungry again. Foods with a low GI are digested more slowly. Blood glucose levels rise more slowly and over a longer period of time, so you feel full for longer. Choosing low GI foods might help maintain a healthy weight and perhaps also prevent certain diseases such as type 2 diabetes.

The table below indicates the glycaemic index of a range of foods. The graph at right shows the blood glucose spike and drop that occur after eating high GI foods, and the more moderate, longer lasting rise in blood glucose level after eating low GI foods.

Foods with a high GI, such as chocolate, cause a sharp rise in blood sugar. Foods with a low GI, such as nuts, result in a more moderate but longer lasting rise in blood sugar.

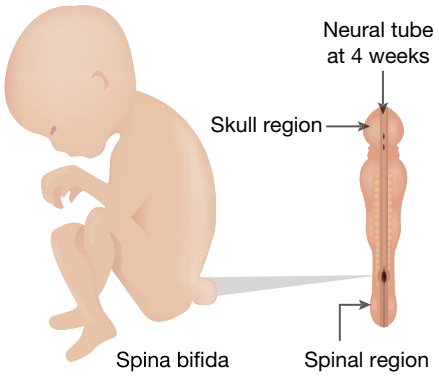


Glycaemic index	Extremely high	High	Moderately high	Moderately low	Low
Grains	Puffed rice Cornflakes White bread	Wholemeal bread Muesli Brown rice Porridge oats	Bran Rye bread White pasta Brown pasta	Tomato soup Lima beans	Barley
Fruit and vegetables	Parsnip Baked potato Carrot	Sweet corn Mashed potato Boiled potato Apricots Bananas	Sweet potato Peas Baked beans Grapes Orange juice	Pears Apples Oranges Apple juice	Red lentils Soybeans Peaches Plums
Sugar	Glucose Honey	Sucrose			
Snacks		Corn chips Chocolate Crackers Biscuits Low-fat ice-cream	Potato chips Sponge cake	Yoghurt High-fat ice-cream	Peanuts

8.6.4 Folate deficiency and neural tube defects

Have you noticed that many breakfast cereals, bread and other foods have folate added? Folate is an important vitamin, particularly for women of child-bearing age. Low levels of folate early in pregnancy can cause a type of birth defect called neural tube defects. Spina bifida is a disease that is the result of a neural tube defect; some of the vertebrae that protect the spinal cord are not formed properly. Symptoms vary greatly depending on the location and extent of the defect but can include paralysis.

Neural tube defects occur when the neural tube does not close up properly early in pregnancy. Spina bifida is a neural tube defect affecting the lower area of the spine.



Dr Fiona Stanley is an Australian scientist whose research was integral to establishing the link between folate deficiency and neural tube defects. She led a team of researchers that collected data on the health of mothers and their babies and looked for patterns in the data. Once the link between folate deficiency and neural tube defect had been established, opinions differed on the best way to tackle this. Some argued that, since pregnant women make up only a small percentage of the population, any strategies to address folate deficiency should focus only on pregnant women and women trying to fall pregnant. Doctors should advise these women to take a folate supplement. Others proposed that, since the highest risk period for neural tube defect is very early in pregnancy, many women would not see a doctor until it was too late for them to begin taking a folate supplement. Adding folate to staple foods such as bread and breakfast cereal would be a more effective way of preventing neural tube defect. In the end, this is the strategy that was adopted.

8.6.5 Vitamin D deficiency

Vitamin D deficiency is becoming more common. This vitamin is found in some foods, but our bodies can also make vitamin D when our skin is exposed to the sun. Vitamin D is important for bone and muscle health, and low levels of vitamin D in early childhood causes the disease rickets. Addressing vitamin D deficiency is a sensitive issue. While exposure to sunlight increases vitamin D levels, it can also cause skin

Vitamin D deficiency is the cause of rickets, a disease where the bones of the legs do not form properly.



A melanoma, the most deadly form of skin cancer. Too much time spent in the sun can cause melanomas and other types of skin cancer to form on the skin.



cancer. Too little sunlight is linked to vitamin D deficiency, but too much causes skin cancer. The ideal amount of exposure depends on skin colour (fair-skinned people need less sun exposure) and the intensity of sunlight.

There is some concern that, in an attempt to address vitamin D deficiency, we might see a rise in the incidence of skin cancer. Perhaps a safer alternative might be to add vitamin D to staple foods.

8.6.6 Science careers: dietitian

Joanne (not her real name) is a dietitian in a large city hospital. She is an expert on the science of food and its effect on the body. She works closely with doctors and other health practitioners and provides expert nutrition and dietary advice to patients. She has also been involved with a number of research projects.

A large part of the work of dietitians is to educate people about the type of diet they should be eating by explaining complex scientific information about nutrition in a way that patients can understand. Patients who have recently been diagnosed with diet-related diseases, such as diabetes, coeliac disease, heart disease and certain types of cancers, are referred to a dietitian to advise them on the types of foods they should eat. Certain medical conditions require that the patient follows a very strict and very specific diet. For example, patients with kidney problems may need to dramatically cut down the amount of salt they take in. This means that ordinary foods such as cheese and rice bubbles can create health problems for them.

Dietitians are also called upon when patients need to be fed through a drip or nasogastric tube (a tube that goes into the nose and down to the stomach). If a patient cannot eat due to a medical condition (such as tongue cancer), a dietitian will calculate how much and what type of food solution the patient needs.

A number of dietitians also do research. For example, Joanne has been involved in a study to assess the effect of patients' nutritional status on the time it takes for them to recover from an injury or illness. She worked out whether the patients were well nourished or malnourished and recorded the length of time the patients stayed in hospital. She showed that malnourished patients needed more time in hospital to recover from their injury or illness.

Not all dietitians work in hospitals. Some dietitians have their own practice (an office where patients come to see them), and other dietitians work with particular communities. Sports dietitians work with athletes and some dietitians work for the government or large companies that manufacture food.

The skills needed to be a dietitian vary with the type of work that they do, but all dietitians need a very good knowledge of food and its effect on the body. Good communication skills are also important as well as strong interpersonal skills (being able to work with people). All dietitians have university qualifications. Some universities require students to complete a science degree before specialising in nutrition.

Joanne, dietitian, giving dietary advice to a patient



A doctor inserting a nasogastric tube into a patient



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. **Outline** some of the health risks associated with childhood obesity.
2. **Outline** why it is important for people with diabetes to monitor and control their blood sugar levels.
3. **Explain** why a person who has type 1 diabetes needs to have regular injections of insulin.
4. **Distinguish** between type 1 and type 2 diabetes.
5. **Outline** why it is important for women who are pregnant to take in sufficient folate.
6. What is spina bifida?
7. What is the cause of skin cancer?
8. Which disease is associated with vitamin D deficiency?

Think

9. Suggest why vitamin D deficiency is becoming more common in Australia.
10. Read through the list of strategies on page 305 that have been proposed to address childhood obesity. Choose three strategies and outline why some groups in society might oppose these strategies.
11. Have a class debate on the following topic: The Australian government should do more to tackle childhood obesity.
12. **Justify** why dietitians need good communication and interpersonal skills.
13. **Identify** other skills that might be important for dietitians.
14. **Explain** why athletes may need to see a dietitian.

Skill builder

15. Study the table on page 306 listing the glycaemic indexes of common foods.
    (a) Are there any general trends?
    (b) Deduce how the fat content of a food affects its GI. (*Hint:* Look at where the high-fat foods are in the table.)
    (c) High-fat ice-cream has a lower GI than low-fat ice-cream. **Discuss** whether it is healthier.

Investigate

16. Osteoporosis, scurvy, atherosclerosis and rickets are all diseases with a dietary link. For each disease, find out what the symptoms are and how the disease is linked to the type of food eaten.
17. Use the **Fiona Stanley** weblink in the Resources tab and other resources to find out more about Fiona Stanley's scientific work. Prepare a PowerPoint presentation summarising her achievements.
18. Use the **Dietitians Association** weblink in the Resources tab to find the name of the university closest to where you live that offers a course that can qualify you to work as a dietitian.

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Explore more with this weblink: Fiona Stanley

Explore more with this weblink: Dietitians Association

8.7 Breathe in, breathe out

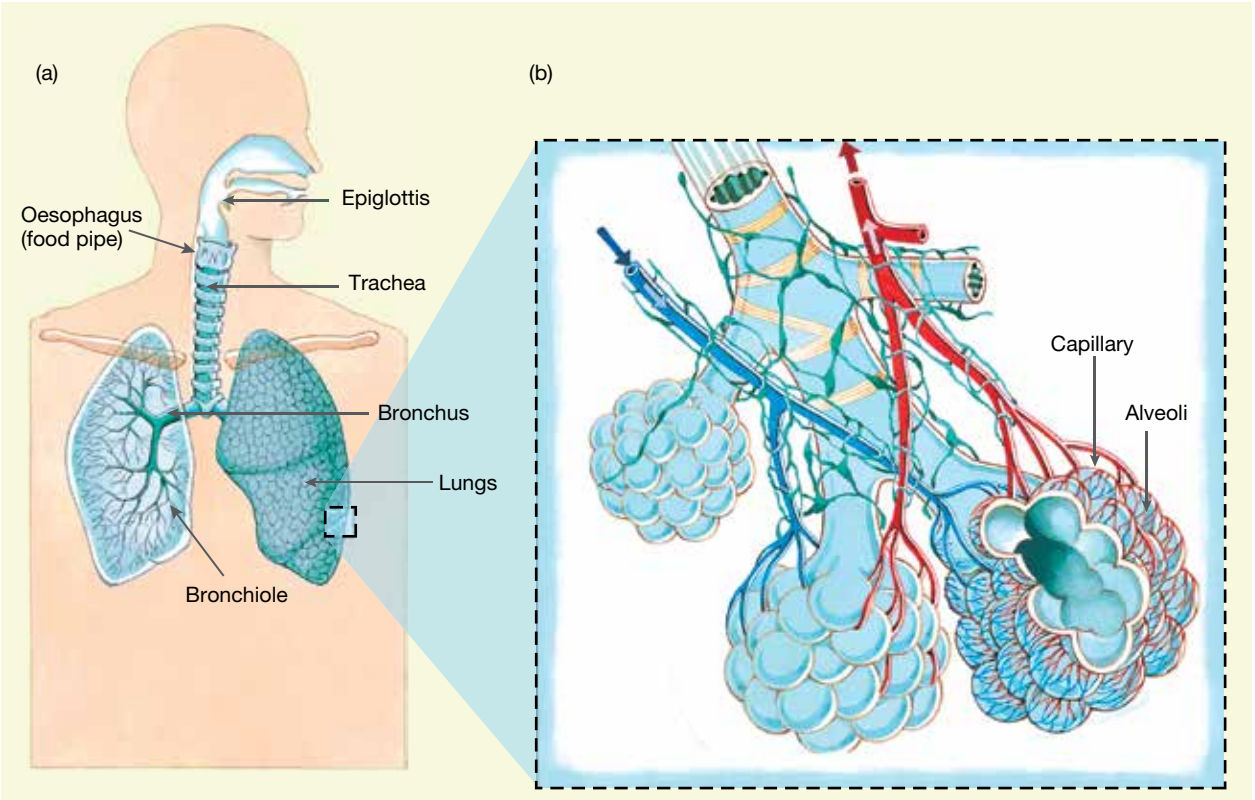
8.7.1 Breathing

Breathe in deeply … Now breathe out. You have just introduced some extra oxygen into your body and removed some unwanted carbon dioxide. You do this about 15–20 times per minute without thinking. The muscle movements required for **breathing** are automatic and controlled by the respiratory centre in the brain.

When you breathe in, you take in the mixture of gases called air. Oxygen and carbon dioxide are gases found in the air around you. Oxygen makes up about 21 per cent of the air, while carbon dioxide makes up

only about 0.04 per cent. Your body uses some of the oxygen you take in. The table below shows that the air that you breathe out contains less oxygen and more carbon dioxide than the air you breathe in. The percentages in the table are approximate and vary a little with weather conditions and height above sea level.

(a) Organs of the respiratory system with (b) a portion of the lung expanded to show details



The air that you breathe enters your body through your nose and mouth. Unless your nose is clogged up by a cold, it is the most important airway. The hairs and sticky mucus in your nose trap dust and dirt and other harmful material such as disease-causing bacteria. Breathing in through your mouth gets the air in faster but without being filtered by the nose. When you play sport, your body uses oxygen more quickly and it is often necessary to breathe in through your mouth, bypassing the filter system in your nose.

What goes in and what comes out

Gas	Oxygen (%)	Carbon dioxide (%)	Water vapour (%)	Nitrogen (%)
Air breathed in	21	0.04	usually <1%	78
Air breathed out	16	4	2	78

HOW ABOUT THAT!

The water vapour that you breathe out carries heat away from your body and helps you to control your body temperature. You lose about 500 mL of water each day by breathing out water vapour.

8.7.2 Going down?

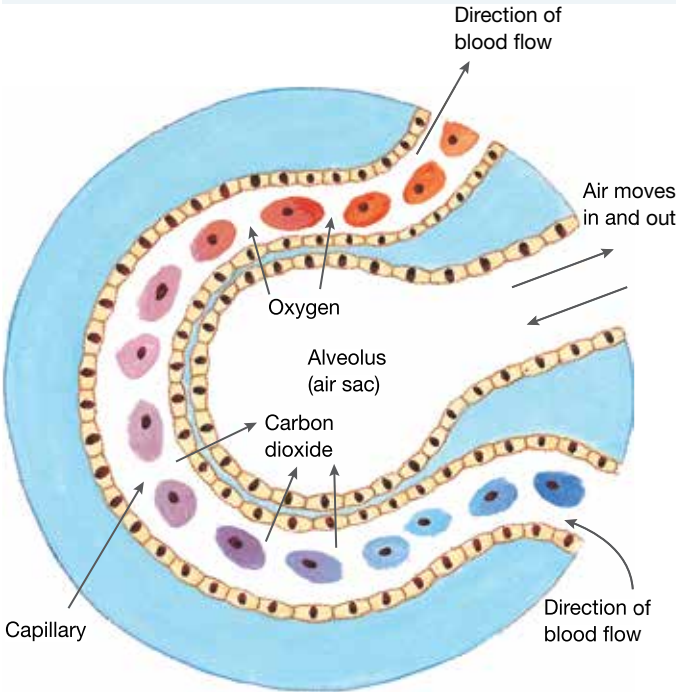
After entering your body, the air moves into a narrow tube called the **trachea**, which is more commonly known as the windpipe. At the top of this tube is a flap of tissue called the **epiglottis**. The job of this tissue is to stop food from going down into your lungs. If food does manage to pass it and 'go down the wrong way', a cough soon brings it back up again.

The trachea divides into two narrower tubes called the bronchi. Each of these tubes leads to a lung. Inside the lung, each tube divides into many smaller tubes called **bronchioles**. The bronchioles branch out, getting smaller and smaller until they end at thousands of tiny air sacs called alveoli.

8.7.3 What happens in an alveolus?

An alveolus is full of air. There are many small blood vessels called **capillaries** that run over the surface of the alveoli. The walls of the alveoli and the walls of the capillaries are very thin. Oxygen passes through these walls from the alveolus into the blood. Carbon dioxide goes in the opposite direction. This is an example of diffusion.

In an alveolus, oxygen diffuses into the blood and carbon dioxide diffuses out of the blood.

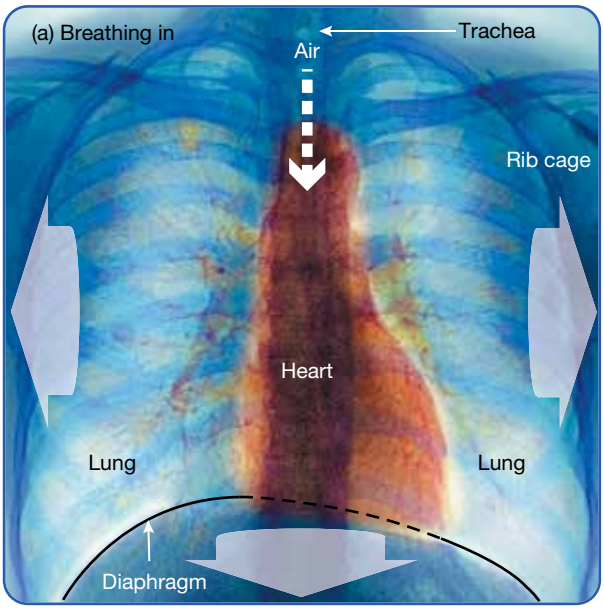


When a substance diffuses across a membrane, it moves in the direction that will even out the concentration on both sides of the membrane. In the lungs, the concentration of oxygen is higher inside the alveoli than in the blood so oxygen diffuses out of the alveoli and into the blood inside the capillaries.

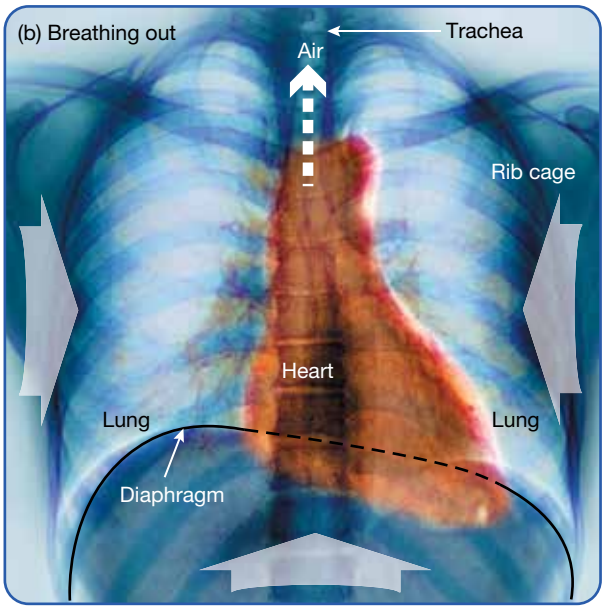
The concentration of carbon dioxide is greater in the capillaries than in the alveoli, so carbon dioxide moves out of the bloodstream and into the alveoli so that it can be breathed out.

The movement of a muscle called the **diaphragm** helps the lungs do their job by pulling in and pushing out air. The diagram below shows how this happens.

(a) **Breathing in.** The diaphragm tightens, allowing the lungs to expand, and the air is pulled into the lungs.



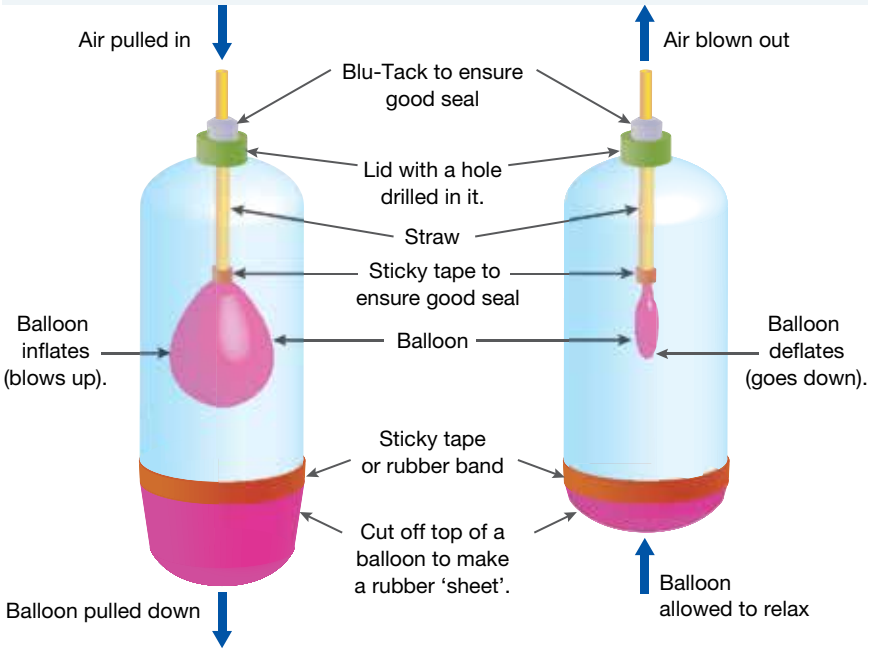
(b) **Breathing out.** The diaphragm relaxes, making the lungs smaller, and the air is pushed out.



8.7.4 Lung capacity

Although adults can breathe out up to 5 litres of air with each breath, they usually breathe out only about half a litre. The largest volume of air that you can breathe in or out at one time is called your **vital capacity**.

A model lung. When the rubber sheet at the bottom is pulled down, the pressure inside the jar drops and air is sucked into the balloon. The balloon inflates (blows up).



INVESTIGATION 8.6

Measuring your vital capacity

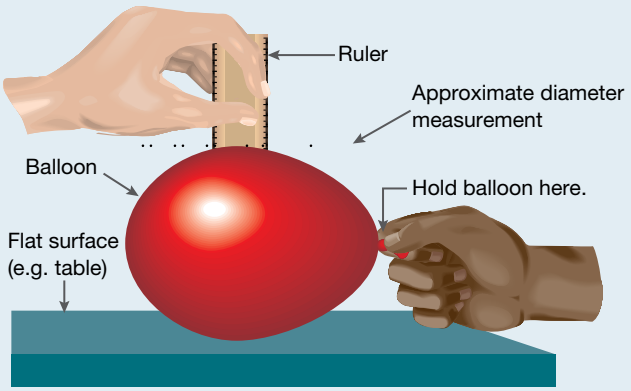
AIM: To compare the vital lung capacities of a number of students

You will need:

balloon
ruler

- Blow up a balloon to about 20 cm in diameter two or three times to stretch it. Release the air each time.
- Take the biggest breath you can, then blow out all the air you can into the balloon. Tie up the end of the balloon to hold in your 'blown out' air.
- Use a ruler to measure the diameter of the balloon as shown at right.
- Use the table at the bottom to determine your approximate vital capacity in litres.
- Release the air from the balloon and repeat your measurement of vital capacity three more times. Average your results to get your best estimate of the maximum 'blow-out' of your lungs.

How to measure the diameter of the balloon



Determining vital capacity

Balloon diameter (cm)	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Approx. vital capacity (litres)	0.3	0.4	0.5	0.7	0.9	1.2	1.4	1.8	2.1	2.6	3.0	3.6	4.2	4.8

Discussion

1. Why were you asked to stretch the balloon first?
2. Why did you measure your vital capacity four times?
3. Draw up a table with the following headings.

(a)

Name	Male or female?	Does this student play a wind instrument?	Lung capacity (L)

(b) Collect results from all the students in your class and complete the table.
(c) Calculate the average lung capacity for all the girls and all the boys. Do girls have a bigger or smaller lung capacity than boys in your class?
(d) Calculate the average lung capacity for all the students in your class who play a wind instrument. Compare that with the average value for the other students in the class. Does playing a wind instrument have an effect on lung capacity?

4. Suggest another way of measuring the amount of air exhaled with each breath.

HOW ABOUT THAT!

Whales, like all other mammals, have lungs. Unlike fish, they need to swim to the surface every so often to take in a huge breath of air. Large whales blow out then breathe in about 2000 litres of air through one or two nostrils on the top of their head. They need only about two seconds at the surface to do this. The air blown out contains a lot of water vapour and forms a cloud or spout that can shoot up to eight metres into the air.



8.7 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. List all of the parts that a molecule of oxygen must go through when travelling from the air into your bloodstream.
2. **Describe** the job done by each of the following parts of the respiratory system.
   (a) Epiglottis (b) Diaphragm (c) Alveoli (d) Lungs

Think

3. The terms ‘breathing’ and ‘respiration’ are often confused with each other. **Differentiate** between these two terms.
4. When you breathe out onto a window on a cloudy day it fogs up.
   (a) **Identify** the substance that makes the window fog up.
   (b) Is the same substance breathed out on warm days? If so, why doesn’t the window fog up?
5. Some people describe the structure of the lungs as an upside-down, hollowed-out tree. **Identify** which parts of the lungs the following parts of a tree might represent.
   (a) Trunk (b) Branches (c) Twigs (d) Leaves
6. Study the diagram of A model lung and answer these questions.
   (a) **Identify** the organs or body parts that the following parts of the model represent.
   (i) Straw
   (ii) Rubber sheet
   (iii) Balloon inside bottle
   (iv) Plastic bottle

(b) Copy and complete the following paragraph.
When you pull down on the rubber sheet, the space inside the bottle becomes _____. There is still the same number of air particles in that space so the air particles move further _____. This makes the air pressure inside the bottle _____ and it causes air to be _____ the straw. When the rubber sheet is let go, the _____ inside the bottle returns to its original size and air is _____ of the straw.
(c) **Explain** why alveoli and capillaries need to have very thin walls.

7. A year 8 student wrote in her exam paper: 'Humans breathe in oxygen and breathe out carbon dioxide'. Her teacher wrote: 'That's not entirely correct. If that were true, then mouth-to-mouth resuscitation could not keep a person alive'.
(a) Rewrite the statement made by the year 8 student so that it is correct.
(b) **Justify** the teacher's comment.
(c) If you breathed in air that had a lower oxygen concentration than your blood, **describe** what would happen in your alveoli.

Investigate

8. **Find** out what a spirometer is.
9. Research then write half a page to **explain** how high altitudes affect your breathing.

Create

10. **Construct** a model lung as shown in the diagram on page 312. You can use the following items:
- two clear 1-litre plastic bottles with tops
- four balloons
- two plastic drinking straws
- rubber bands or very sticky tape
- plasticine or Blu-Tack
- scissors.

11. Use the **Anatomy of breathing** weblink in the Resources tab to view an animation that outlines how the respiratory system works.

learnon RESOURCES — ONLINE ONLY

Explore more with this weblink: Anatomy of breathing

Complete this digital doc: Worksheet 8.6: Breathing — constructing a report (doc-12412)

8.8 Blood highways

8.8.1 Blood by the bucketful

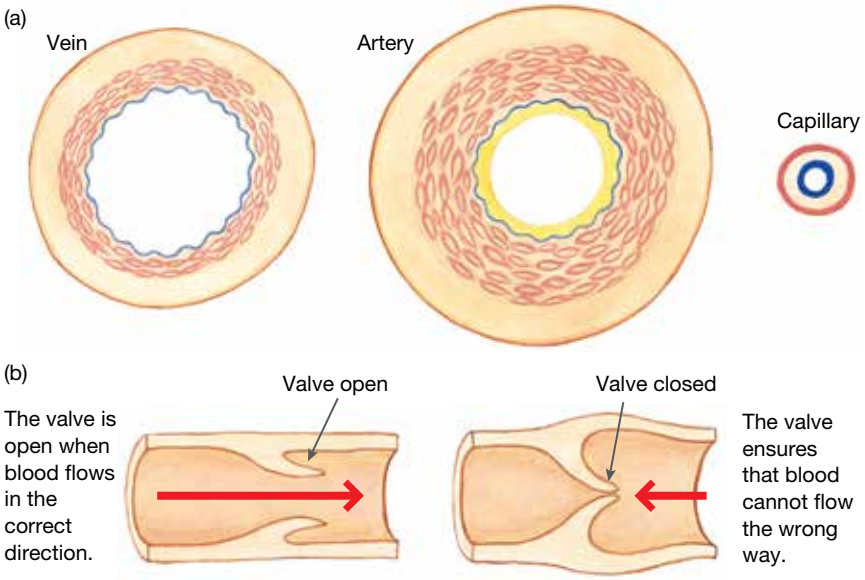
The respiratory system gets oxygen into our lungs. Once the oxygen is in the lungs, it needs some way of getting to all the cells of the body. That is the job of the **circulatory system**. The circulatory system consists of the heart, the blood vessels and blood.

An average-sized human has about five litres of blood; that's about a bucketful. It travels around the body in tubes called **blood vessels**. If these vessels were laid end to end, they would encircle the Earth two and a half times. These tubes enable materials in your body to be transported from one place to another.

Some of these blood vessels are called **arteries**. They have thick, elastic, muscular walls and carry blood under high pressure away from your heart. Some other vessels are called veins. They have thinner walls, and valves that prevent the blood from flowing backwards. Veins carry blood to the heart.

The most numerous and smallest blood vessels are called capillaries. Your body contains about 1 000 000 km of capillaries, which penetrate almost every tissue. No cell is very far away from one. Capillaries are very important blood vessels because they carry materials such as oxygen and nutrients to the cells and remove wastes including carbon dioxide.

(a) Cross-sections of an artery, a vein and a capillary. (b) Veins have valves to ensure that blood flows in only one direction.



8.8.2 What's in blood?

The liquid part of blood is called **plasma**. It is a straw-coloured liquid and consists mostly of water. Many of the substances carried around in the blood are dissolved in the plasma. Nutrients such as glucose and some waste products, including carbon dioxide, are dissolved in the plasma.

The reason that blood looks red is that it contains many red blood cells. In a drop of blood there are about 300 million red blood cells. They are red because they contain a chemical called **haemoglobin**.

The job of red blood cells is to carry oxygen around the body. When red blood cells reach the lungs and oxygen diffuses into the blood, the oxygen reacts with the haemoglobin in red blood cells to form a chemical called **oxyhaemoglobin**, which is bright red. So blood that contains a lot of oxygen is actually brighter red than blood that is low in oxygen. In fact, the colour of blood can provide an indication of its oxygen saturation level. In hospital, it is common for a small device that emits red light to be clipped to a patient's finger. The device is called a pulse oximeter. Most people undergoing surgery have a pulse oximeter attached. The device is used in other instances as well. The device emits two types of light. The proportion of each type of light that is absorbed as the light passes through the patient's finger depends on the level of oxygen in the blood, and hence its colour. A finger that contains highly oxygenated blood absorbs more of one type of light than a finger containing poorly oxygenated blood. The device provides a handy way of measuring a patient's oxygen saturation level without the need to draw blood to analyse it.

A sample of blood that has been centrifuged (spun at high speed). The cells are in the bottom layer. They have separated from the plasma.



Red blood cells have a biconcave shape.



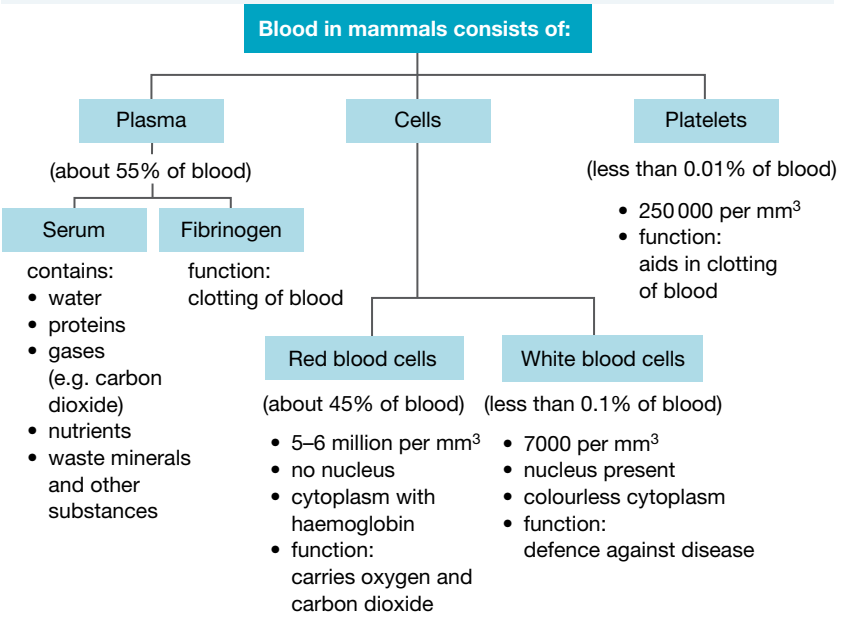
Red blood cells are very small so they can fit inside tiny capillaries. They form from cells in the bone marrow and, when mature, they lack a nucleus. This saves space. They also have a concave shape. This means that, for their size, they have a large surface area that allows them to carry lots of oxygen.

8.8.3 White blood cells and platelets

There are a lot fewer **white blood cells** in blood but they are larger than red blood cells and have a nucleus. White blood cells have an irregular shape and are not rigid so they can squeeze into small blood vessels. They are involved with fighting disease. Some white blood cells engulf (gobble up) germs while others produce substances called **antibodies**, which attack germs. When you are sick, the number of white blood cells in your blood increases.

Platelets are also found in blood. Platelets help blood to clot if a blood vessel is cut. This seals up the cut so that germs cannot get in.

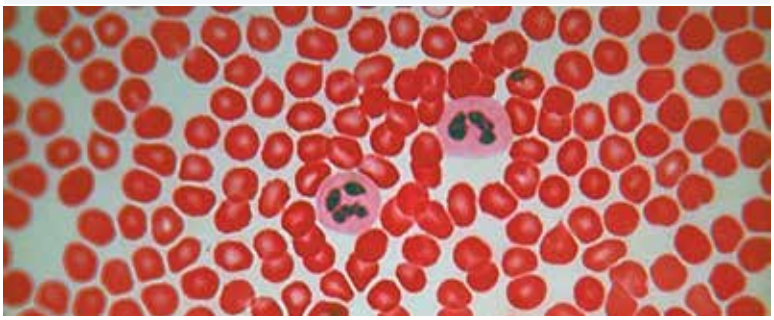
The components of blood



HOW ABOUT THAT!

Insect blood looks a little like raw eggwhite, because it contains no pigment. The blood of crabs and crayfish, however, contains the pigment haemocyanin. This pigment has copper in it and is blue when combined with oxygen. This is different from haemoglobin in humans, which is red when combined with oxygen.

Human blood cells seen through a light microscope. The white blood cells are shown as pink, each with a nucleus.



INVESTIGATION 8.7

Viewing blood cells

AIM: To draw a diagram of blood cells viewed under a microscope

You will need:

prepared slide of blood smear
microscope

- View the prepared slide under the microscope on high power.
- Find a white blood cell on the slide.

Discussion

1. Sketch a few red blood cells and one white blood cell.
2. Estimate how many red blood cells would fit inside a white blood cell.
3. Estimate the number of red blood cells that can fit across the field of view.

8.8.4 Artificial blood — a reason to support scientific research

If you lose a lot of blood, you may need a blood **transfusion**. The blood from another person is injected into your veins to replace the blood you have lost. However, donated blood is always in short supply and the blood that is transfused must match your own blood type. If the person who donated the blood had an infection, there is also a risk of passing on that infection. What's the solution? Artificial blood.

No-one has quite succeeded as yet in making a perfect replacement for blood but a number of teams of scientists around the world are working on it. The ideal blood replacement would be a product that has a long shelf life, does not need to be refrigerated, does not need to match the patient's blood type and is guaranteed to be free of disease-causing germs.

A type of artificial blood called Hemopure has been approved to treat some cases of severe anaemia in South African hospitals. It is made from haemoglobin obtained either from blood that has passed its use-by date or from animal blood. The haemoglobin is wrapped in certain chemicals so that it behaves a lot like red blood cells do and can carry oxygen around the body.

Hemopure is not an ideal replacement for donated blood, and it has not been approved for human use in Australia. There are side effects to using this product but, in countries where there is a critically low supply of donated blood, the benefits of this blood substitute can outweigh the risks.

Other blood substitutes are also being tested. Some of these are completely synthetic and are not even red in colour. PFCs are blood substitutes that are white in colour. They carry out only some of the functions of blood, mainly transporting substances including oxygen around the body.

8.8 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. **Outline** what blood is and what it does.
2. Name and **describe** the types of blood vessels in which blood travels around your body.
3. **Compare** red blood cells, white blood cells and blood platelets.
4. **Explain** the advantage of red blood cells not having a nucleus.
5. **Explain** why haemoglobin is important.
6. Why isn't blood the same colour in all animals?

Think and analyse

7. The higher the altitude, the less oxygen there is in the air. **Propose** a reason why people living at high altitudes usually have more red blood cells than people living at low altitudes.
8. The components of blood diagram shows the composition of blood. **Construct** a divided bar graph that shows what proportion of blood consists of plasma, red blood cells, white blood cells and platelets.
9. Copy and complete the following: There are _____ times more red blood cells than white blood cells in blood.

Investigate

10. Research one of the following circulation topics and **summarise** your findings to the class in a poster or PowerPoint presentation: blood transfusions, rhesus babies, varicose veins, leukaemia, haemophilia, thrombosis, embolisms, aneurisms.
11. Find out more about how blood circulates in insects and lobsters.

Discuss

12. With a partner, **construct** a PMI (see page 681) for a law that makes it compulsory for everyone over 16 to donate blood at least once a year.

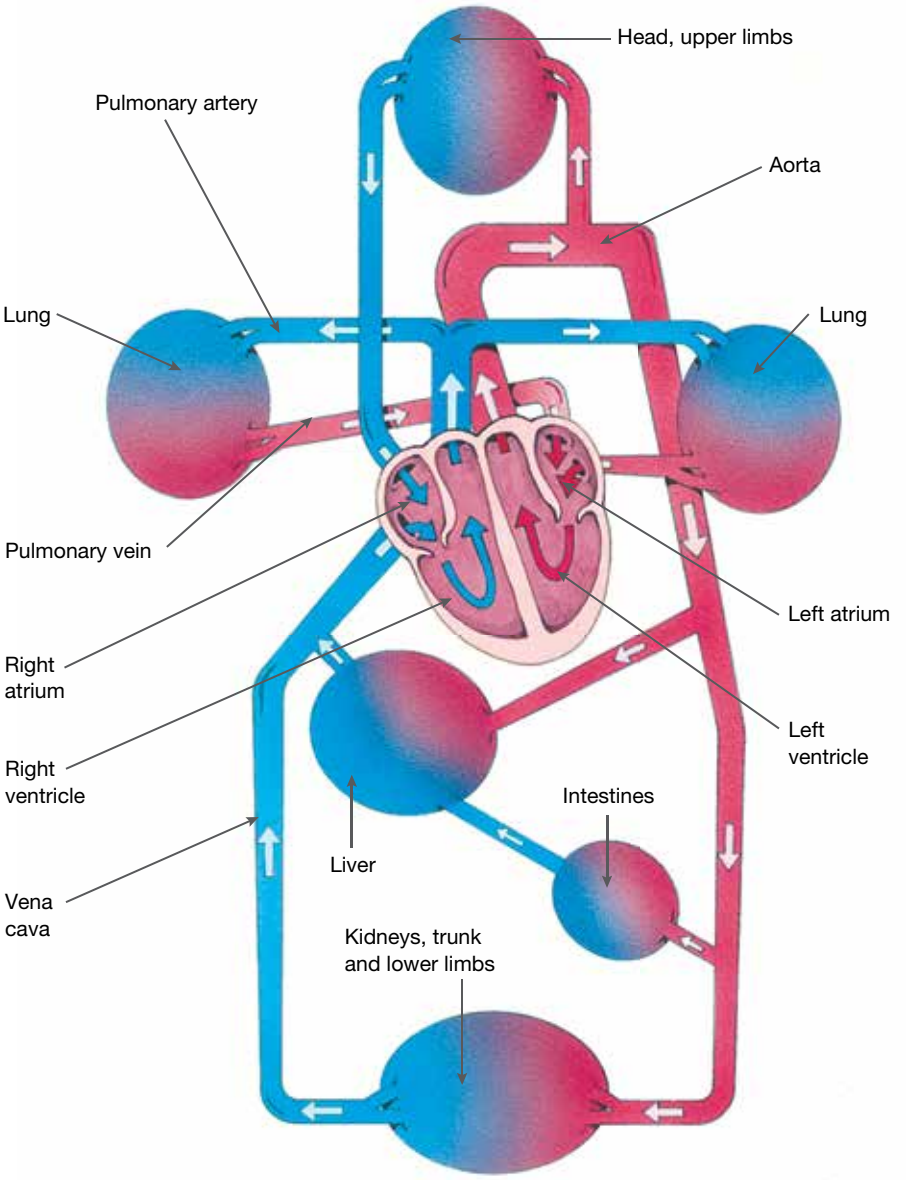
8.9 Have a heart

8.9.1 Two pumps in one

Often linked with emotions, love and courage, the heart has a special meaning for most of us. In a clinical sense, however, it is merely a pump about the size of your clenched fist.

To be more precise, the human heart is actually *two* pumps. Veins bring blood back from all parts of the body to the heart. The veins join up into a large vein called the **vena cava**. This vein leads into the top right chamber of the heart. The blood is then pushed into the bottom right chamber. From here it is pumped out to your lungs where it picks up oxygen and becomes more reddish in colour. It also loses some of the carbon dioxide from it. The **oxygenated** blood then returns to the left-hand side of your heart to be pumped out again to your body tissues, where it delivers oxygen and nutrients. The **deoxygenated** blood then returns to the right-hand side of the heart for the cycle to be repeated.

Connected highways — the routes for blood circulation



Four chambers

The human heart has four chambers. The upper two chambers are called the **left atrium** and **right atrium** (plural = atria), and the lower two chambers are the **left ventricle** and **right ventricle**. The two sides of the heart are different. The walls of the left side are thicker and more muscular because they need to have the power to force the blood from the heart to the rest of the body.

Flap-like structures attached to the heart walls, called **valves**, prevent the blood from flowing backwards and keep it going in one direction. If you listen to your heart beating you will hear a **'lub dub'** sound. The 'lub' sound is due to the valves between the ventricles and atria shutting. The 'dub' sound is due to the closing of the valves that separate the heart from the big blood vessels that lead to the lungs and the rest of the body.

HOW ABOUT THAT!

Not all animals have four-chambered hearts; in fact, some don't have hearts at all! A fish heart has two chambers, while amphibians and reptiles have three-chambered hearts. Can you suggest any advantages or disadvantages of these hearts over a four-chambered mammalian heart?

INVESTIGATION 8.8

Dissect a heart

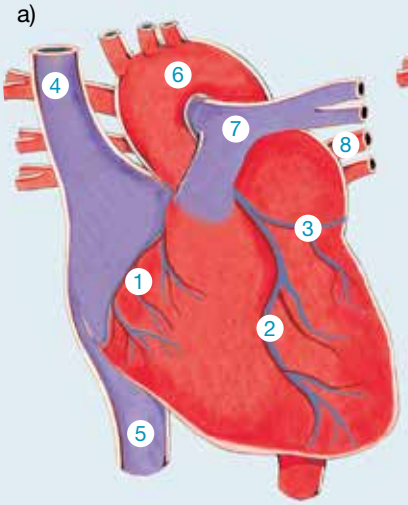
AIM: To investigate the structure of a mammalian heart

You will need

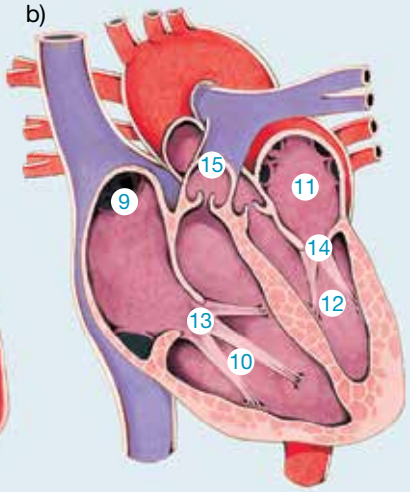
sheep's heart preferably with the blood vessels still attached
dissecting instruments
dissecting board

- Place the heart on the dissection board as shown in diagram (a) below. Use the diagram to identify the external parts of the heart.
- Try to locate where blood enters and leaves the heart:
  (a) to and from the lungs
  (b) to and from the rest of the body.
- Sketch and label the heart and use arrows to show the direction of blood flow.
- Cut the heart in two so that both halves show the two sides of the heart (similar to diagram (b) at right).
- In a diagram, record your observations of the thickness of the walls on the left side of the heart compared with the right side.
- Suggest reasons for the differences observed.
- Try to locate the valves in the heart.

a)



b)



1 Right coronary artery
2 Left anterior descending coronary artery
3 Circumflex coronary artery
4 Superior vena cava
5 Inferior vena cava
6 Aorta
7 Pulmonary artery
8 Pulmonary vein
9 Right atrium
10 Right ventricle
11 Left atrium
12 Left ventricle
13 Tricuspid valve
14 Mitral valve
15 Pulmonary valve

Discussion

1. Find out the role of the coronary arteries.
2. Find out what causes a heart attack.
3. Describe the valves and suggest their function.
4. Write a summary paragraph about the structure and function of the heart.

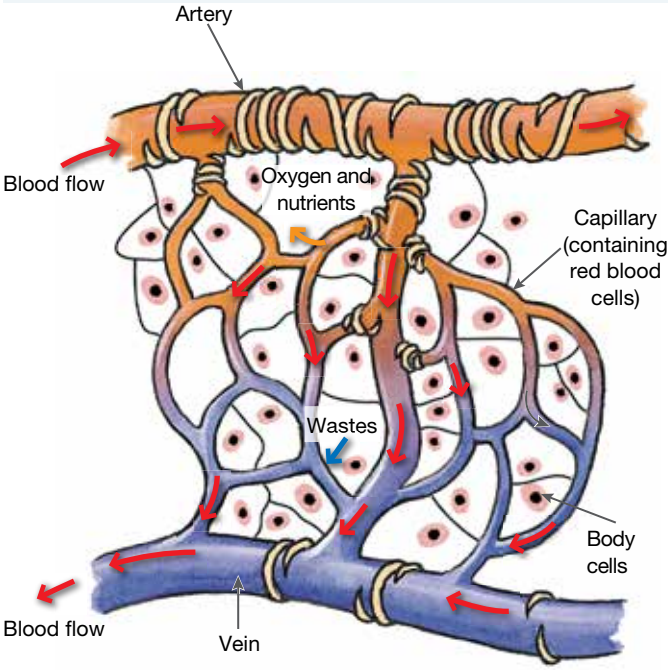
8.9.2 Connected highways

Blood travels to all parts of the body in the capillaries. Oxygen and nutrients move out of the blood and pass through the walls of the capillaries. Waste products, including carbon dioxide, move out of cells and pass through the walls of the capillaries and into the bloodstream. Carbon dioxide is removed in the lungs. Other waste products are filtered out of the blood as it passes through the kidneys.

There are also many capillaries associated with the intestines. The digestive system breaks down food into particles that are small enough to diffuse through the walls of the intestines and into the blood. These nutrients are then delivered to all cells by the bloodstream.

Blood also passes through the liver. Your liver has numerous functions, including sorting, storing and changing digested food. It removes fats and oils from the blood and modifies them before they are sent to the body's fat deposits for storage. It also converts ammonia into urea. Ammonia is a toxic substance produced when protein is metabolised. Urea is less toxic than ammonia and can be filtered out of the blood by the kidneys. The liver also changes other dangerous or poisonous substances so that they are no longer harmful to the body. Your liver is something you cannot do without.

In the capillaries, oxygen diffuses out of the blood and waste produced by cells diffuses into the bloodstream.



Your blood vessels make up a very busy highway system!

8.9.3 Blood pressure

The heart's pumping action and the narrow size of the blood vessels result in a build-up of considerable pressure in the arteries. The force with which blood flows through the arteries is called **blood pressure**. It is affected by different activities and moods. It also goes up and down as the heart beats, being highest when the heart contracts (**systolic pressure**) and lowest when the heart relaxes (**diastolic pressure**). A person's blood pressure is expressed as a fraction. This fraction is the systolic pressure over the diastolic pressure: for example, 120/70.

Keeping the pace

Each minute that you are sitting and reading this, about 5–7 litres of blood completes the entire circuit around your body and lungs. In a single day, your heart may have beaten about 100 000 times and pumped about 7000 litres of blood around your body.

A normal human heart beats about 60–100 times a minute, this rate increasing during exercise or stress. With each **heartbeat**, a wave of pressure travels along the main arteries. If you put your finger on your skin just above the artery in your wrist, you can feel this **pulse** wave as a slight throb. Your pulse rate immediately after exercise can be used as a guide to your physical fitness. The fitter you are, the less elevated your heart rate will be after vigorous exercise.

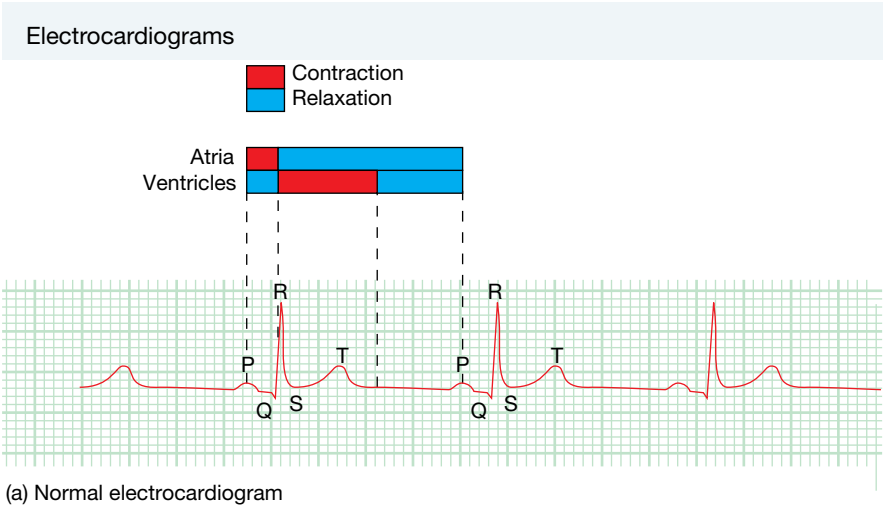
The regular rhythmic beating of the heart is maintained by electrical impulses from the heart's **pacemaker**, which is located in the wall of the right atrium. Some people with irregular heartbeats are fitted with artificial electronic pacemakers to regulate the heart's actions and correct abnormal patterns.

Try clenching your fist every second for five minutes. Getting a little tired? The heart is made up of special muscle called **cardiac muscle**, which never tires. Imagine having a 'cramp' or 'stitch' in your heart after running to catch the bus! Due to its unique electrical properties, heart muscle will continue to beat even if it has been removed from the body. Scientists have shown that even tiny pieces of this muscle cut from the heart will continue to beat when they are placed in a test tube of warm salty solution.

8.9.4 Getting the beat!

An **electrocardiogram (ECG)** shows the electrical activity of a person's heart. ECG patterns are valuable in diagnosing heart disease or abnormalities.

To produce the ECG, electrodes (flat pieces of metal that are connected to the ECG machine by wires) are stuck to the skin. The machine measures the tiny electrical impulses produced by the heart as it beats. It produces a trace similar to the one shown in the diagram below. An abnormal trace could indicate that the patient has arrhythmia. This is a condition where the heart beats irregularly. Another reason for an unusual trace could be a cardiac infarction. In this condition there is dead tissue in the heart. The electrical signal cannot travel through the dead tissue so the ECG looks abnormal. There are many other conditions that can cause an unusual ECG, and doctors will often follow up an abnormal ECG with further tests.



(a) Normal electrocardiogram

(b) Abnormal electrocardiogram

INVESTIGATION 8.9

Check your heart

AIM: To investigate the short-term effects of exercise on heart rate and blood pressure

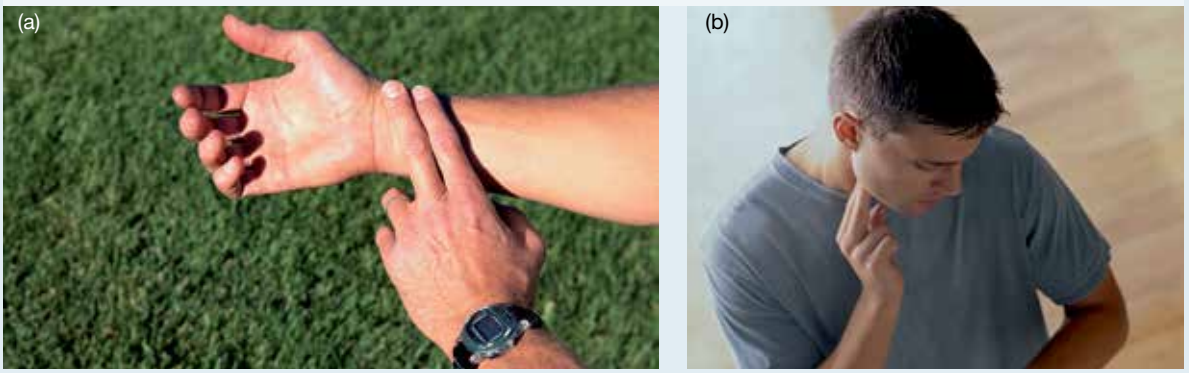
You will need:

stopwatch

blood pressure monitor

- Find your pulse, either on the inside of your wrist or in your neck (see the illustrations). Make sure you use two fingers, not your thumb, to find your pulse.

Two places where your pulse should be easy to find: (a) radial location (wrist) and (b) carotid location (neck)



- Measure your heart rate in beats per minute (bpm) by counting the number of times your heart beats in 15 seconds and then multiplying this number by 4.
- Measure your blood pressure using the blood pressure monitor.
- Go for a walk in the playground or around the school oval. Measure your heart rate and blood pressure again.
- Run up and down a flight of stairs. Measure your heart rate and blood pressure again.
- Copy the table below in your notebook and enter your own results.

Test	Heart rate (bpm)	Blood pressure (mm Hg)
Before exercise		
After walking		
After running up stairs		

Discussion

1. What effect does exercise have on heart rate and blood pressure?
2. Design and carry out an experiment to test the following hypothesis: 'There is a link between a person's resting heart rate and the number of hours the person spends exercising each week'.

8.9 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 each term with its description:

Term	Description
(a) Vein	A Blood vessel taking blood away from the heart
(b) Atria	B Organ where oxygen diffuses into the bloodstream and carbon dioxide is removed
(c) Liver	C Organ that pumps blood around the body
(d) Small intestine	D Organ with numerous functions, including converting toxic ammonia into urea, which is less toxic and can be filtered out of the blood by the kidneys
(e) Ventricles	E Organ where nutrients including glucose, amino acids and fatty acids move from the digestive system into the bloodstream
(f) Heart	F The top two chambers of the heart
(g) Artery	G The bottom two chambers of the heart
(h) Lung	H Blood vessel taking blood back to the heart

2. **Contrast** the following:
   (a) the blood in the two sides of the heart
   (b) the structures of the two sides of the heart
   (c) systolic and diastolic pressure.
3. **Explain** why there are valves in the heart.
4. **Define** the terms 'systolic blood pressure' and 'diastolic blood pressure'.
5 (a) **Recall** how many times a normal human heart beats each minute.
   (b) **Outline** what might cause the rate of heartbeats to increase.
   (c) **Outline** how the rhythmic beating of the heart is maintained.
6. **Explain** what an electrocardiogram is and when is it useful.
7. **Describe** how an ECG is used to detect heart abnormalities.
8. **Describe** what is unusual about cardiac muscle.
9. **Explain** why you can't live without your liver.

Think and create

10. (a) Copy the 'connected highways' diagram on page 320 into your notebook.
    (b) Use a coloured pencil to show the path taken for a red blood cell to travel from the pulmonary vein to the pulmonary artery, if it goes via the intestines.
11. Mark the following sites (a, b, c, d) on your diagram. In which blood vessel(s) would you expect the highest:
    (a) blood pressure
    (b) blood glucose levels
    (c) blood carbon dioxide level
    (d) oxygen level?
12. List the following in the order that a red blood cell would reach them after leaving the aorta.

    pulmonary artery, left ventricle, right atrium, intestine, lung, pulmonary vein, left atrium, liver, right ventricle

13. Convert your classroom or sports oval into a 'circulatory highway system'. Pretend to be a red blood cell and travel along the route it would take around the body.
14. (a) Read through the information on pages 318–319 to refresh your memory on the structure and function of your heart.
    (b) **Construct** a flow chart to show the movement of blood through your body using the following labels. left atrium, right atrium, right ventricle, left ventricle, pulmonary artery, pulmonary vein, lungs, aorta, vena cava, from body, to body

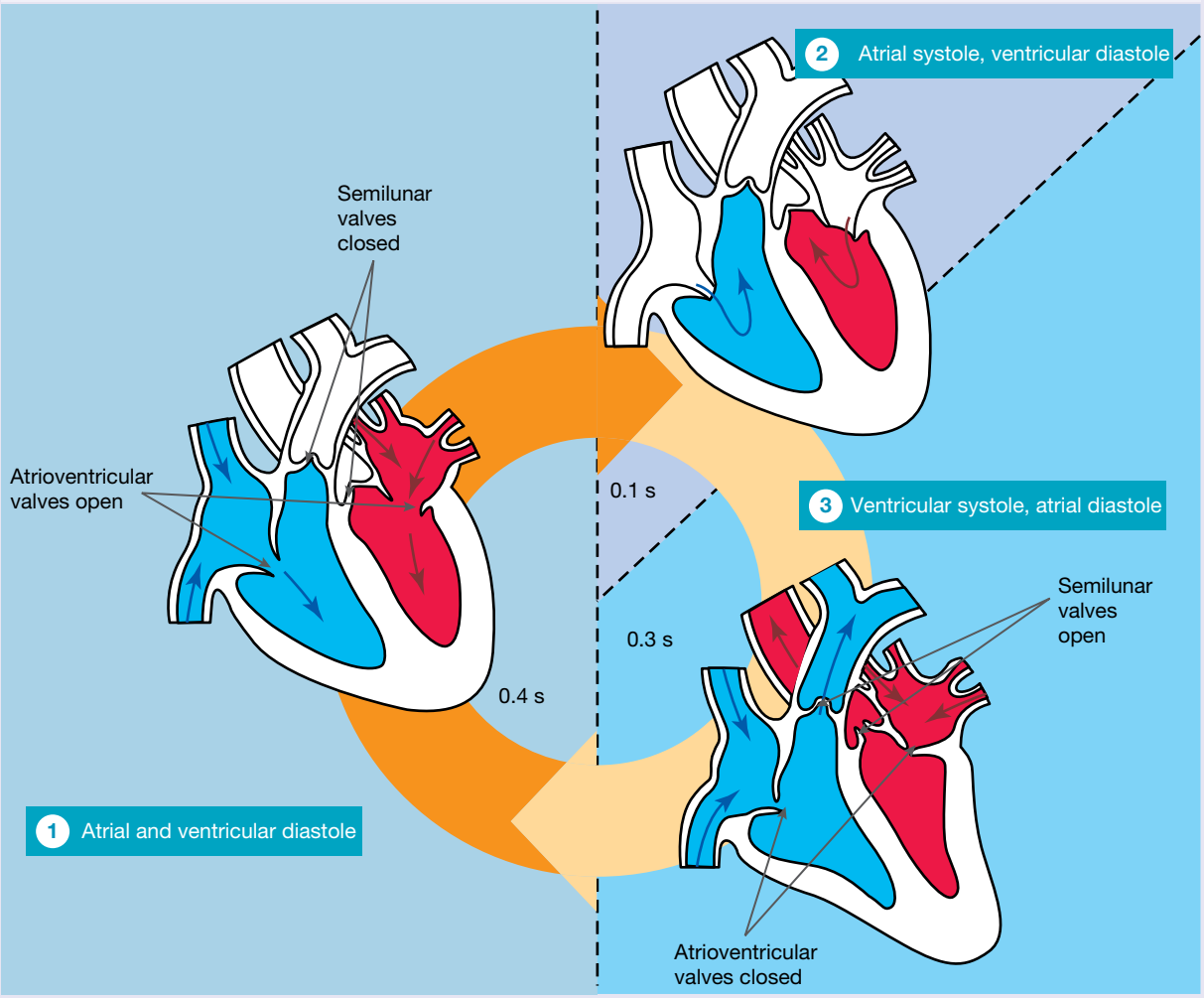
Skill builder

15. **Interpret** the cardiac cycle on the next page to answer the following questions.
    (a) In which stage do the atria contract?
    (b) In which stage do both the atria and ventricles relax?
16. Systole is the contraction of your heart muscle and diastole is the relaxation of your heart muscle. **Propose** what the following might mean.
    (a) Atrial systole
    (b) Ventricular systole
    (c) Atrial diastole
    (d) Ventricular diastole
17. **Interpret** the electrocardiograms on page 321 to answer the following questions.
    (a) At 'P', are the muscle cells of the atria contracted or relaxed?
    (b) After the 'QRS' wave, is the ventricle relaxed or contracted?
    (c) How does the normal electrogram differ from the abnormal electrogram?
    (d) Suggest what might be wrong with the heart activity shown on the abnormal electrogram.
18. **Compare** the information in the ECG on page 321 with the diagram on the next page. Which sections of the normal ECG correspond to each of the stages of the cardiac cycle shown in the diagram?

Investigate

19. Hypertension or high blood pressure has been called 'the silent killer'. Find out about high blood pressure and answer the following questions.
    (a) What do doctors consider to be high blood pressure?
    (b) **Outline** how high blood pressure can lead to death.
    (c) **Outline** what people with high blood pressure can do to bring their blood pressure back to normal.

One complete cardiac cycle can take about 0.8 seconds in an adult human with a pulse of about 75 beats per minute.



Source: Fig. 42.6, p. 876 from BIOLOGY, 6th ed. by Neil A. Campbell and Jane B. Reece. Copyright © 2002 by Pearsons Education, Inc. Reprinted by permission.

20. Test your ability to label the parts of the heart by completing the **Beat it!** interactivity in the Resources tab.
21. Use the **Electrocardiogram game** weblink in the Resources tab to simulate performing ECGs on patients referred to you by medical doctors.

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Try out this interactivity: Beat it! (int-0210)

Complete this digital doc: Worksheet 8.7: Blood and blood highways (doc-12413)

Explore more with this weblink: Electrocardiogram game

8.10 Getting rid of waste

8.10.1 The urinary system

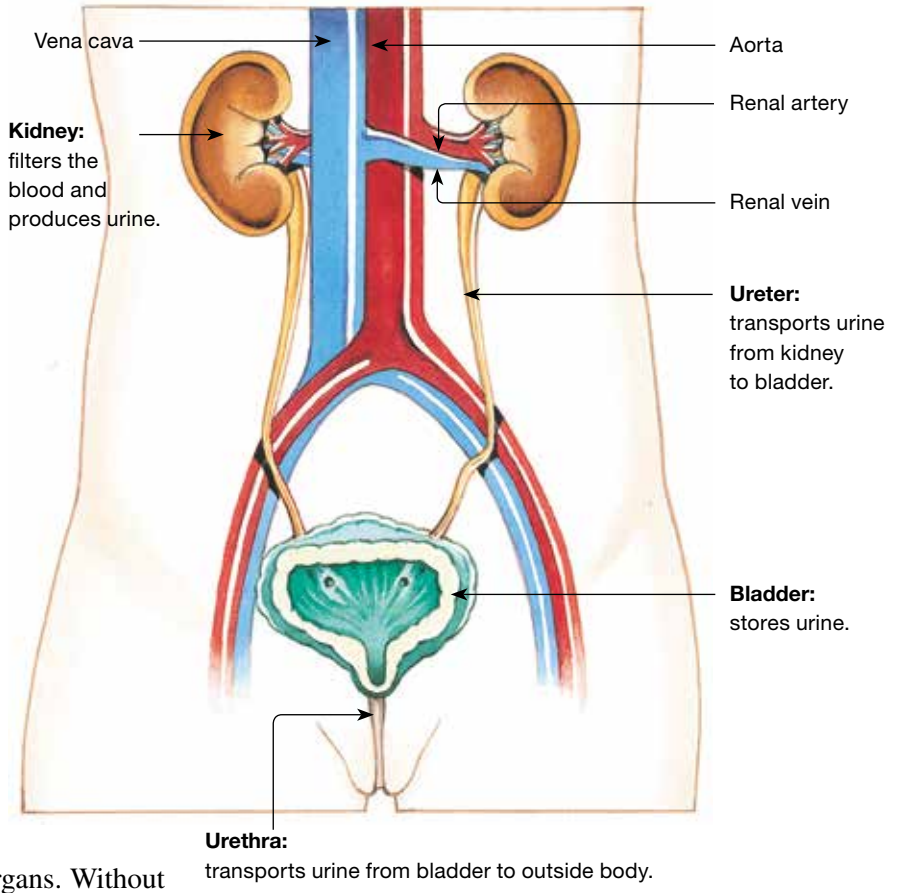
The human body takes in substances including food, water and oxygen. It also needs to get rid of unwanted substances that are produced by the body.

A number of organs are involved in getting rid of waste, including the lungs, the liver, the skin and the organs that make up the urinary system.

Many of the chemical reactions that occur inside cells produce toxic waste products. If our bodies could not get rid of these we would die. Excretion involves the removal of these harmful substances from the body. Carbon dioxide, produced in respiration, is excreted via the lungs; we breathe it out. Our skin excretes some salts and water in the form of sweat. Another harmful substance we need to excrete is urea. In the liver, excess amino acids are converted to urea. Urea is carried away from the liver in the blood-stream. The kidneys remove urea from the blood.

If you put your hands on your hips, your kidneys are close to where your thumbs are. You have two of these reddish-brown, bean-shaped organs. Without them you would survive only a few days.

The urinary system



Kidneys play an important role in filtering your blood. About a quarter of the blood that your heart pumps is sent to your kidneys. These small organs filter about 50 litres of blood each hour. As blood passes through the kidneys, the urea and some other harmful substances are removed. Other substances, like salts and water, which may be in excess, can also be removed. This keeps their concentration in the blood constant. If this did not occur, your cells would not work properly.

Urine is produced by your kidneys. This watery fluid contains unwanted substances. Tubes called **ureters** transport urine from your kidneys to your **bladder** to be stored temporarily. As it fills, your bladder expands like a balloon. It can hold about 400 mL of urine. **Urination** occurs when urine moves from your bladder through a tube called the **urethra** and out of your body.

8.10.2 Blood, water and urine

Both blood and urine are mostly made up of water. Water is very important because it assists in the transport of nutrients within and between the cells of the body. It also helps the kidneys do their job because it dilutes toxic substances and absorbs waste products so that they may be transported out of the body.

A comparison of what is found in the blood and the urine. How are they different?

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

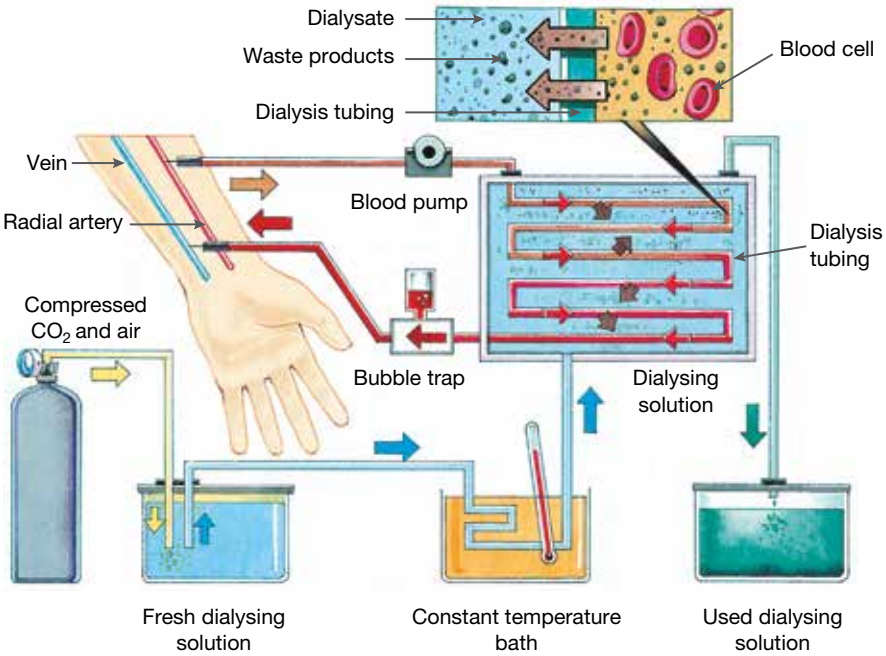
Too much or too little

The concentration of substances in the blood is influenced by the amount of water in it. If you drink a lot of water, more will be absorbed from your large intestine and the kidneys will produce a greater volume of dilute urine. If you do not consume enough liquid, you will urinate less and produce more concentrated urine.

8.10.3 Kidney failure

People with kidney disease may not be able to remove waste materials from their blood effectively. Kidney disease is more likely to affect people who have diabetes, high blood pressure or inflammation of the kidney. Kidney failure occurs when the kidneys become so inefficient that waste products start to build up in the blood. It is life threatening and often the only cure is a kidney transplant. People whose kidneys do not work properly may need to have haemodialysis treatment. Tubes are attached to the arm of the patient and their blood is pumped out of their body into a machine that does the job of the kidneys — it removes urea and other substances from the blood. The blood then goes back into the body.

Haemodialysis



8.10.4 Getting rid of alcohol

Drinking excessive amounts of alcohol is linked to many health risks. The part of the digestive system that is most affected by alcohol is the liver. The liver breaks down alcohol. Enzymes in the liver convert alcohol first to a substance called acetaldehyde, then to acetate, and finally into carbon dioxide and water. The carbon dioxide diffuses out of the bloodstream in the lungs and is breathed out. The water leaves the body as urine, sweat or vapour in the breath.

If you drink alcohol faster than the liver can break it down, the alcohol that is not eliminated is absorbed in the body and you become intoxicated. The liver works at a fixed rate and can detoxify about one standard drink each hour. So coffee, cold showers, fresh air and vomiting do not speed up the process of getting rid of alcohol from your body.

Alcohol also affects the amount of urine produced by the kidneys. It reduces the body's production of a hormone that keeps urine concentrated. The kidneys produce more urine than usual, instead of reabsorbing water into the body. As a result, you urinate more and can become dehydrated. In extreme cases, a heavy drinker can lose so much water that the body cannot function properly.

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'. Penguins, on the other hand, may appear to have runny noses because that is where their salt-secreting glands are located.

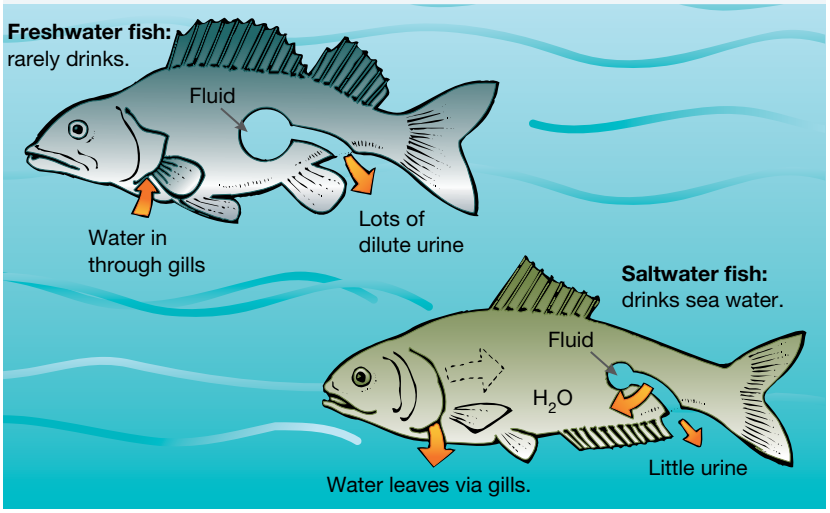
8.10.5 What type of waste?

Has a bird dropping ever landed on your head or car window? If so, you have probably noticed that bird droppings are quite different from the type of waste produced by humans. We produce large amounts of urine. To

produce this urine we need to take in a considerable amount of water. Consuming that much water and storing large volumes of urine in a bladder would weigh birds down. Birds produce their waste in the form of solid uric acid. It is even less toxic than urea, so the birds can store it in their bodies without the need to dilute it in water, and they pass it out of their bodies along with their faeces. Reptiles and insects also excrete their waste in the form of uric acid, mainly because they tend to live in dry regions where conserving water is important.

For fish and other aquatic animals, conserving water is not necessary. They save energy by releasing their waste in the form of ammonia. Ammonia is highly toxic but, for animals that live in water, this is not a great problem. They are able to release the ammonia directly into the water and thus dilute it to reduce its toxicity.

Which type of fish rarely drinks?



Birds excrete their waste in the form of uric acid.



8.10 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 term 'excretion'.
2. Draw and label a diagram of the urinary system showing the following: renal arteries, renal veins, ureters, bladder, urethra.
3. What do blood and urine have in common?
4. **Outline** two effects of drinking large amounts of water.
5. **Describe** one way in which excess salt is removed from your body.
6. **Explain** how haemodialysis can assist people with kidney disease.

Think

7. **Outline** what happens to alcohol in the liver.
8. Look carefully at the haemodialysis diagram on page 326 and suggest reasons why the following are included in the process:
   (a) blood pump (b) bubble trap (c) constant temperature bath.
9. **Identify** what you would expect to find in the used dialysing solution.
10. **Explain** why red blood cells don't pass through the dialysis tubing.
11. **Compare** dialysis with the way a real kidney works.

Skill builder

12. Use the table on page 325 and the other information on pages 324–327 to answer the following questions.
    (a) **Construct** two divided bar graphs to show the quantity of water, proteins, glucose, salt and urea in blood and in urine.

(b) **Identify** which substance is in the greatest quantity in both blood and urine. Suggest a reason for this.
(c) **Identify** the substances found only in blood.
(d) **Identify** the substances found in urine in a greater quantity than in blood. Suggest a reason for this.
(e) **Explain** why the concentration of urea in the urine may vary throughout the day.

Investigate

13. Research and report on one of these conditions: urinary incontinence, kidney stones, dialysis, kidney transplants, cystitis.
14. Find out:
    (a) the differences between the urethra in human males and females
    (b) why pregnant women often need to urinate more frequently
    (c) how the prostate gland in males may affect urination in later life
    (d) which foods can change the colour or volume of urine
    (e) which tests use urine in the medical diagnosis of diseases.
15. People who regularly drink large amounts of alcohol are at greater risk of developing liver problems. Find out about a medical condition called cirrhosis of the liver and why heavy drinkers are at greater risk of this disease.
16. Use the **Alcohol** weblink in the Resources tab to find out about the effects of alcohol on various parts of the body.

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Complete this digital doc: Worksheet 8.8: Removing waste from the blood (doc-12414)

Explore more with this weblink: Alcohol

8.11 Bodies on the move

8.11.1 Muscles

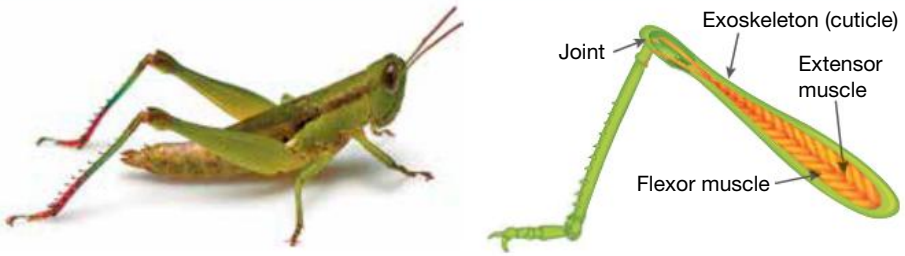
Muscles use the energy from food to enable us to move. They move the bones they are attached to, allowing us to walk, run, lift objects and perform fine movements such as those involved in writing. Together, muscles and bones form the musculoskeletal system, the system responsible for body movements.

Muscles are tough and elastic fibres. You have muscles to make your heart pump, muscles to help you digest food and muscles to help you breathe. Many muscles, however, are joined to bones. Muscles pull on bones by **contracting**, or shortening. Muscles never push.

The movement of muscles is controlled by the brain, which sends signals through your nerves. Muscles such as those that make your heart pump and those that control your breathing are called **involuntary muscles**. They work without you having to think. The muscles that are connected to bones are called **voluntary muscles** because you have to choose to use them.

In animals without bones, such as worms and slugs, the muscles bring about movement by stretching and shortening certain parts of the body. It can be quite an effective way to move in water. Squid and jellyfish, for example, can propel themselves reasonably quickly in water even though their muscles are not attached to hard parts. They achieve this by pumping water into body cavities and releasing it suddenly to provide thrust. On land, this option is not available. To achieve high speeds on land, it is necessary for muscles to be anchored to something rigid. Insect muscles are attached to a layer of tough material on the outside of their bodies. This layer is called the **exoskeleton**. It is made of a substance called chitin. The following diagram shows how insects can move by contracting and relaxing their muscles.

The muscles in insects are attached to the exoskeleton, the outer covering of the body. This grasshopper can extend its leg by contracting the extensor muscle and relaxing the flexor muscle.



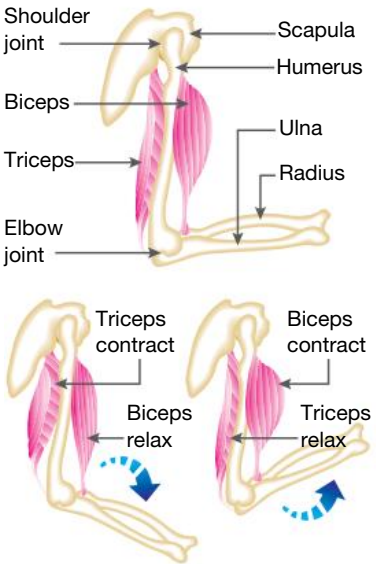
8.11.2 Bones

In humans and other vertebrates (animals with a backbone), the muscles are attached to bones inside the body by bundles of tough fibres called tendons. The muscles move the bones by contracting and relaxing.

There are more than 200 bones in the skeleton of an adult human. Apart from providing a rigid structure for muscles to attach to, thus allowing you to move, the skeleton also has two other important functions. The skeleton provides support and forms a frame that gives your body its basic shape.

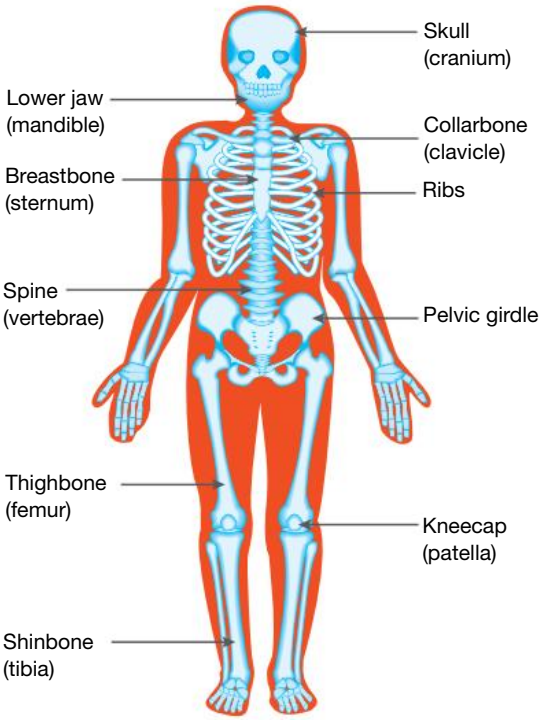
Certain bones of the skeleton also protect vital organs. For example, the brain is protected by the bones of the skull, and the heart is protected by the rib cage.

When your biceps contract, your arm bends upwards. When your triceps contract, your arm straightens.



Without a skeleton, you would be a jelly-like blob.



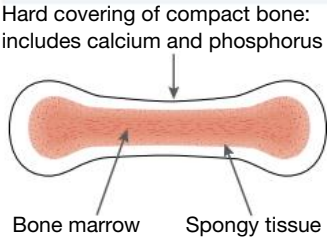


8.11.3 What's in a bone?

Long bones, such as the shaft of the femur (in your thigh), have an outer layer of hard, strong **compact bone** that covers an interior of spongy tissue containing the **bone marrow**. Some of the most important parts of your blood are made in the bone marrow. Some other bones in your body, such as the head of the femur, are made up of lighter **spongy bone**, which is more open in structure than compact bone.

Bones are alive. They contain living cells and need a blood supply to provide oxygen and other nutrients. If bones were not alive, how would you grow taller? How would a broken arm or leg mend?

The structure of a bone



Your bones cannot remain hard without an adequate supply of two important minerals: **calcium** and **phosphorus**. In fact, until you reach the age of about 20, the soft **cartilage** that made up your skeleton when you were born is being gradually replaced. Cartilage is very soft and rubbery, not as hard and solid as bone.

The hardening of your bones as you get older is called **ossification**. After ossification, the bone is made up of about 70 per cent non-living matter and 30 per cent living matter. As you get old, your bones may get dry and brittle. That is why older people break their bones more easily.

Not all cartilage changes into bone. The ends of your bones remain covered in cartilage. Your trachea (windpipe), nose and ears are made mostly of cartilage.

Investigation 8.10 shows what could happen to your bones without a supply of important minerals.

INVESTIGATION 8.10

Rubbery bones

AIM: To investigate the effect of vinegar on bones

You will need:

2 chicken or turkey bones
2 jars
vinegar

- Clean the two chicken or turkey bones and leave them to dry overnight. Place one bone in a jar of vinegar and the other in a jar of water.
- Allow the bones to soak for at least three days. Then remove the bones and observe any changes.

Vinegar is an acid and dissolves minerals such as calcium and phosphorus compounds, removing them from the bone.

- Return the bone to the jar of vinegar for another week, then remove and observe any further changes in the bone. Try to tie the bone in a knot.

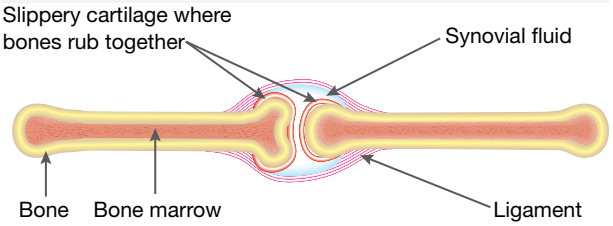
Discussion

1. What changes occurred in each of the two bones?
2. How did the bone change after more than a week in vinegar?
3. Why was the jar of water used in the first part of this experiment?

8.11.4 Joints

A joint is where two bones meet. The elbow and knee are examples of joints. At a joint the bones are held together by bundles of strong fibres called **ligaments**. The ends of each bone are covered with cartilage. The cartilage is covered with a liquid called **synovial fluid**. Together, the cartilage and synovial fluid stop the bones from scraping against each other.

The region where bones meet is called a joint.



Most joints allow your bones to move. The amount and direction of movement allowed depends on the type of joint.

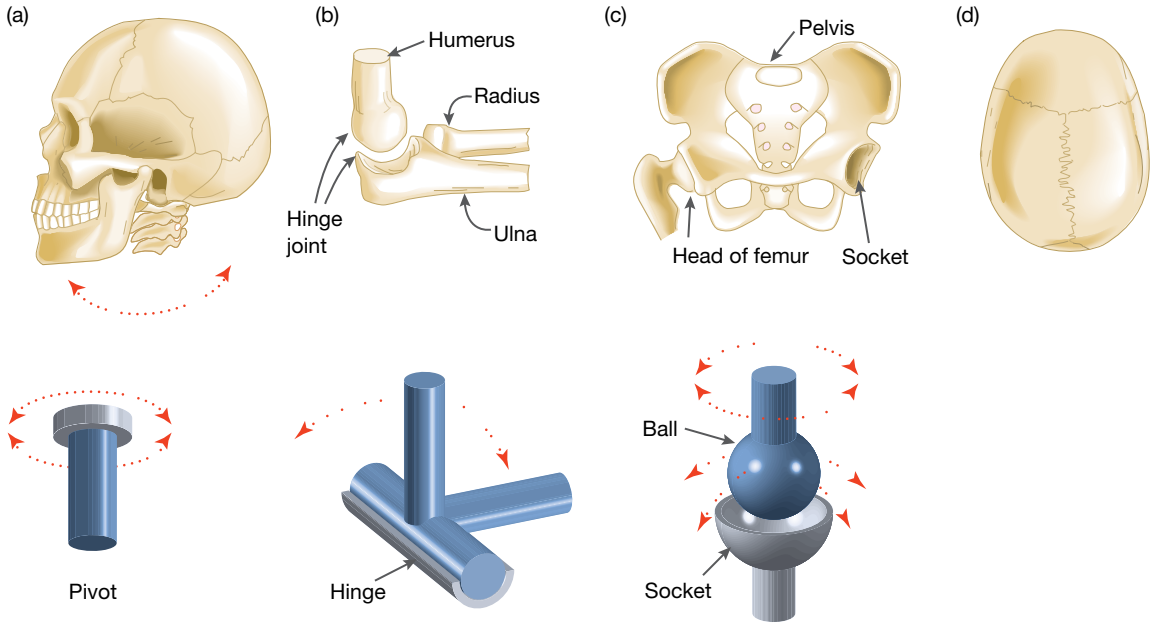
The knee and elbow are **hinge joints**, like those in a door. They allow movement in only one direction.

The hip and shoulder joints are **ball and socket joints**. They allow movement in many directions.

The joint between your skull and spine is a **pivot joint**. It allows a twisting type of movement.

Some joints, such as those that join the plates of your skull, do not move. Such joints are called **immovable joints**. While not allowing movement, these joints provide a thin layer of soft tissue between bones. Their job is to absorb enough energy from a severe knock to prevent the bone from breaking.

Different types of joints: (a) pivot joint, (b) hinge joint, (c) ball and socket joint, (d) immovable joint



8.11.5 Broken bones

When a bone breaks, the ends of the bone need to be put back into place (set), so that they can grow together. If a bone is shattered into several pieces, it is sometimes possible to use pins or wire to hold the pieces in place while the bone heals. A **greenstick fracture** occurs when the bone cracks but does not break. Greenstick fractures are common in children because the bones are more flexible.

Osteoporosis

Osteoporosis is a loss of bone mass that causes bones to become lighter, more fragile and easily broken. It occurs in middle-aged or elderly men and women. In Australia, about 60 per cent of women and about 30 per cent of men are affected in some way by osteoporosis. It is believed to be caused by a lack of calcium in the diet. Insufficient exercise is also an important factor in the development of osteoporosis.

In your teen years, you can help protect yourself from getting osteoporosis later by having a healthy diet. It should include dairy products such as milk, cheese and yoghurt and other foods high in calcium. Such a diet will help ensure that your bone mass is adequate as an adult.

INVESTIGATION 8.11

Chicken wing dissection

AIM: To investigate the structure of a chicken wing

You will need:

chicken wing
scalpel
scissors
dissection tray or board
newspaper
disposable gloves

- Using the scissors and scalpel, gently pull away the skin from the chicken wing. Put the tip of the scalpel blade between the skin and the muscle to separate the skin from the muscle.
- When you have completely removed the skin from one joint, inspect it carefully. Follow each muscle near this joint from one end of the muscle to the other. Try pulling on the muscle. Can you get the bones to move by pulling on the muscle?
- Use scissors to cut through the joint. As you do so, look for tendons and shiny white cartilage.

Discussion

1. Sketch one of the joints in the chicken wing. Label the bones, the tendons and the muscles. Show clearly where the muscle inserts (attaches to the bones). Use arrows to show how the bones move when the muscle is shortened.
2. Feel the cartilage with a gloved hand. Does the cartilage feel rough or slippery? Why does it need to be slippery?
3. Is cartilage harder or softer than bone?

8.11 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.

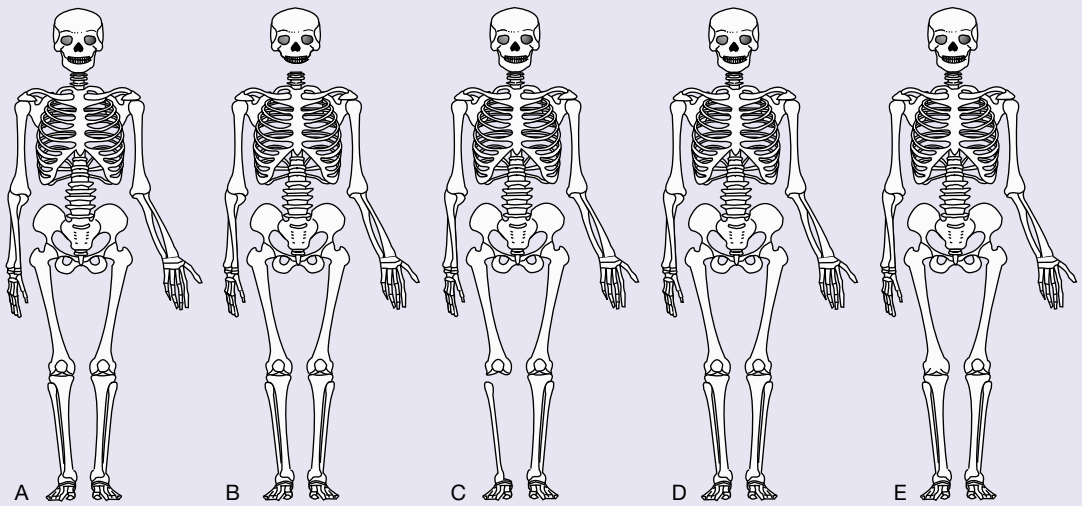
Remember

1. Cover up the diagram of the human skeleton on page 329 and test your memory of the names of some of your important bones by completing the table at right.
2. **Describe** the job done by each of the following parts of a joint.
   (a) Ligament
   (b) Cartilage
   (c) Synovial fluid
3. Some joints are referred to as immovable joints. What is the use of having joints that don't move?
4. **Identify** an example of each of the following types of joint.
   (a) Hinge
   (b) Ball and socket
   (c) Pivot
   (d) Immovable
5. Ligaments and tendons are bundles of tough fibres. **Identify** the major difference between a ligament and a tendon.
6. **Describe** the action of the biceps and triceps muscles as you bend your elbow to raise your forearm.
7. **Recall** which organs the skull and rib cage protect.

Scientific name	Common name
Vertebral column	
	Skull
Clavicle	
	Breastbone
Mandible	
	Thighbone
Patella	
	Shinbone

Think and investigate

8. Look carefully at each of the skeletons below. Three of them are incomplete. **Identify** which skeletons are incomplete and name the missing parts.



9. **Explain** why our skeleton isn't made of just one bone.
10. **Explain** why it is that, in a similar accident, an adult gets a broken bone while a child may suffer only a greenstick fracture.

11. Find out where the following bones are in the human skeleton.
    (a) Humerus
    (b) Fibula
    (c) Coccyx
    (d) Scapula
12. The muscles in your food pipe contract and relax to push food down into your stomach. Are these muscles voluntary or involuntary muscles? **Explain** your answer.
13. **Describe** what would happen if the cartilage in your knee joint wore out.

Create

14. **Construct** a skeleton mobile to hang from the ceiling.
    (a) Trace the skeleton diagram on page 329 (or a larger one from another book), colour it and cut it into a number of sections.
    (b) Paste each section onto cardboard and thread the sections together to make a skeletal mobile.

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Complete this digital doc: Worksheet 8.9: Bones, joints and muscles (doc-12415)

8.12 Review

8.12.1 Study checklist

Multicellular organisms

- **explain** why multicellular organisms need specialised organs and systems 8.2
- **outline** the relationship between cells, tissues, organs and systems 8.2

Digestion and nutrition

- **explain** why animals need to eat food 8.3
- **describe** the roles of carbohydrate, protein, lipid, vitamins and minerals in the diet 8.3
- label a diagram of the digestive system 8.4
- **describe** the function of the main organs of the digestive system 8.4
- **distinguish** between mechanical and chemical digestion 8.5
- **describe** the role of teeth in digestion 8.5
- **describe** the role of enzymes in digestion 8.5

Dietary deficiencies

- **outline** some of the reasons why health professionals are concerned about rising levels of childhood obesity and some strategies that have been proposed to address the issue 8.6
- **describe** diseases linked to vitamin D and folate deficiency 8.6
- **summarise** information about the work of dietitians 8.6

Circulatory and respiratory system

- **describe** the roles of the respiratory system and circulatory system in maintaining humans as functioning organisms 8.7–8.9
- **explain** how air goes in and out of the lungs 8.7
- **describe** what happens in an alveolus 8.7
- **identify** and **describe** the components of blood 8.8
- **describe** the structure of the heart 8.9
- **explain** how the heart works to circulate blood through the body 8.9

- **define** the terms ‘blood pressure’, ‘pulse’ and ‘heart rate’ **8.9**
- **outline** how blood circulation relates to the removal of waste products from the body **8.10**

Excretory system

- **explain** why excretion of waste is essential **8.10**
- label a diagram of the urinary system **8.10**
- **describe** the roles of the main organs of the excretory system **8.10**
- **define** the term ‘haemodialysis’ **8.10**

Musculoskeletal system

- label the major bones of the human skeletal system **8.11**
- **outline** the role of the skeletal system **8.11**
- **explain** how muscles and bones work together to allow movement **8.11**
- **describe** the structure of bones **8.11**
- **identify** examples of hinge, pivot and immovable joints in the body **8.11**

Individual pathways

ACTIVITY 8.1
Investigating body systems
doc-10557

ACTIVITY 8.2
Analysing body systems
doc-10558

ACTIVITY 8.3
Investigating body systems further
doc-10559

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FOCUS ACTIVITY

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Work in groups of three or four students to design a body system board game. It could be based on a familiar board game such as snakes and ladders or trivial pursuit but it needs to include questions that relate to body systems.

Access more details about focus activities for this topic in the Resources tab (doc-10556).

8.12 Review 1: Looking back

assessON

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 table.

Name of tissue	Two organs in this system	Name of system
Nerve tissue	_____, spine	
Cardiac muscle tissue	Heart, _____	

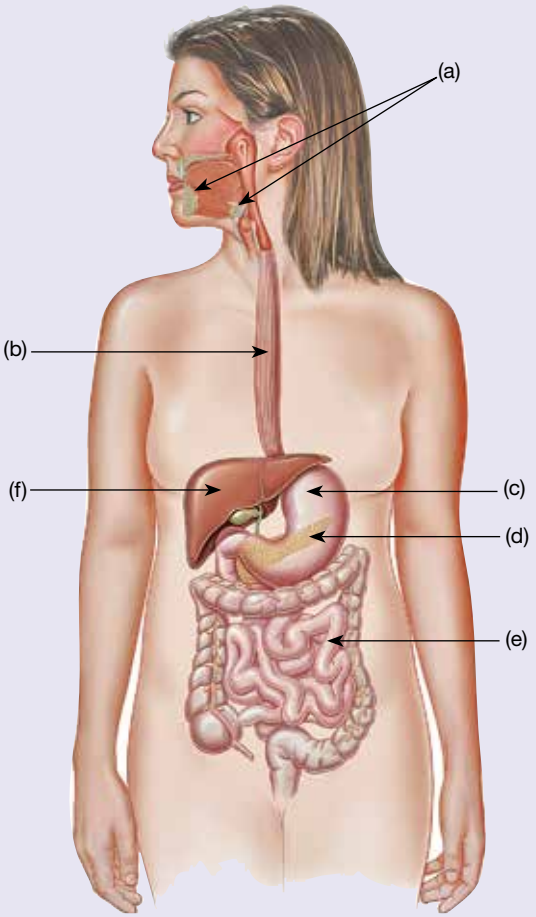
2. Complete the table below to **summarise** what you know about some of the substances in food.

Nutrient	Why is it needed?	In which foods is it found?
Carbohydrates		
Fats and oils		
Proteins		
Vitamins		
Minerals		
Fibre		

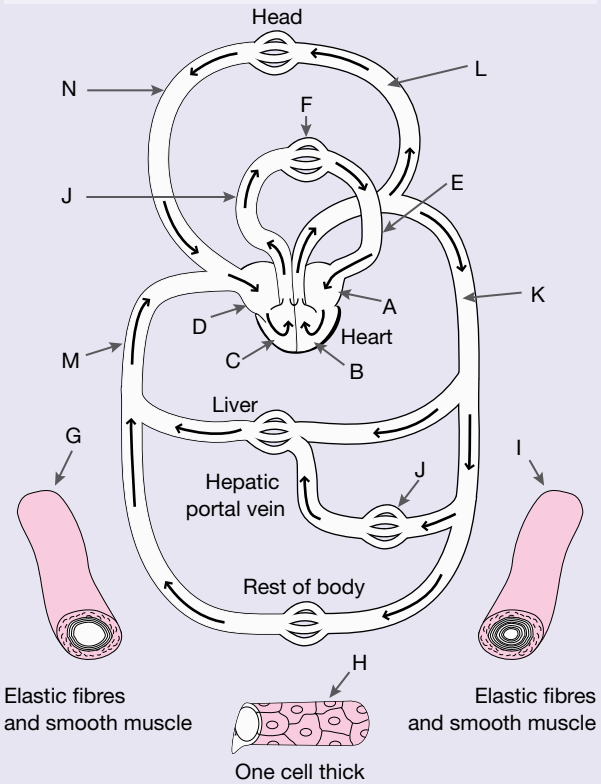
3. **Identify** the names and roles of the organs marked in the diagram at right of the human digestive system.
4. (a) What is the purpose of digestion?
   (b) **Explain** the difference between mechanical and chemical digestion.
5. **Explain** why the small intestine is actually a long tube with many folds and lined with finger-like projections called villi.
6. Copy and complete the following table.

Dietary deficiency	Foods that are high in this vitamin	Symptoms of deficiency
Vitamin D deficiency		
Folate deficiency		

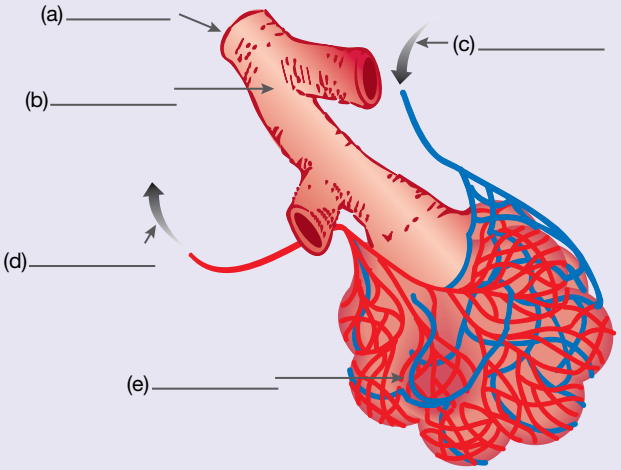
7. **Contrast** type I and type II diabetes.
8. (a) Name the lettered parts (A to N) of the human circulatory system and blood vessels in the diagram below.
   (b) Trace or copy the diagram below. Then use a red pencil to colour in the blood vessels with oxygenated blood, and a blue pencil for those with deoxygenated blood.
   (c) State whether the blood in the following blood vessels is deoxygenated or oxygenated:
      (i) K
      (ii) J
      (iii) N
      (iv) E
      (v) L.
   (d) Draw up a table that shows the differences in structure and function of the arteries, veins and capillaries.



The human circulatory system



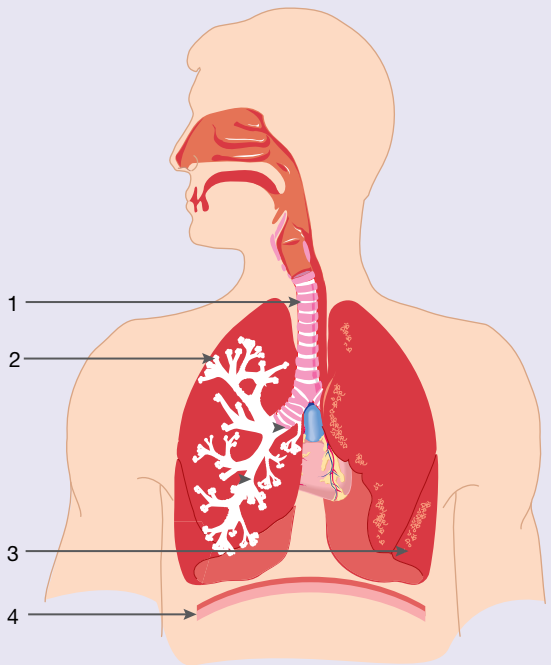
9. The diagram at right shows an alveolus. Match the letters in the diagram with the correct labels from the following list.
   Alveolus
   Bronchiole
   Air flows into the lungs
   Deoxygenated blood
   Oxygenated blood



10. **Identify** all the body parts that oxygen would need to travel through to get from the air you inhale through your nose to the cells in your big toe.
11. **Outline** the function of each of the following organs of the urinary system: bladder, ureter, kidney, urethra, renal vein, renal artery.
12. Draw a diagram to show how a hinge joint works. Show the muscles in your diagram and use arrows to show how the muscles move the bones.

Test yourself

1. In which part(s) of the digestive system does mechanical digestion occur?
   (A) Mouth only
   (B) Mouth and stomach
   (C) Mouth and small intestine
   (D) Small intestine and large intestine **(1 mark)**
2. Which organ removes urea from the bloodstream?
   (A) Bladder
   (B) Liver
   (C) Kidney
   (D) Urethra **(1 mark)**
3. Look at the diagram of the circulatory system shown previously. Which label is pointing to an artery that contains blood that has a much lower oxygen concentration than most arteries?
   (A) E (B) J (C) N (D) K **(1 mark)**
4. A diagram of the respiratory system is shown below.



   The parts labelled 1 to 4 are
   (A) trachea, alveolus, lung and diaphragm.
   (B) bronchus, trachea, lung and diaphragm.

(C) larynx, lung sacs, diaphragm and rib.
(D) trachea, alveolus, intercostal muscles and pulmonary artery. **(1 mark)**

5. What is the main function of the circulatory system?
   (A) To carry out respiration
   (B) To get rid of waste
   (C) To transport substances around the body
   (D) To break down food into small particles **(1 mark)**
6. (a) **Describe** the role of teeth in the process of digestion. **(1 mark)**
   (b) **Justify** why humans have different types of teeth.
   (c) What are enzymes? **Describe** their role in digestion. **(1 mark)**
7. **Explain** why multicellular organisms such as humans need to have specialised organs such as a heart and lungs. **(2 marks)**
8. **Outline** three functions of the skeleton. **(3 marks)**
9. **Explain** why kidney failure is a life-threatening condition. **(2 marks)**

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Complete this digital doc: Worksheet 8.10: Body systems 1 puzzle (doc-12416)
Complete this digital doc: Worksheet 8.11: Body systems 1 summary (doc-12417)
Complete this digital doc: Worksheet 8.12: Body systems 2 puzzles (doc-12418)
Complete this digital doc: Worksheet 8.13: Body systems 2 summary (doc-12419)

TOPIC 9
The structure and properties of matter

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.

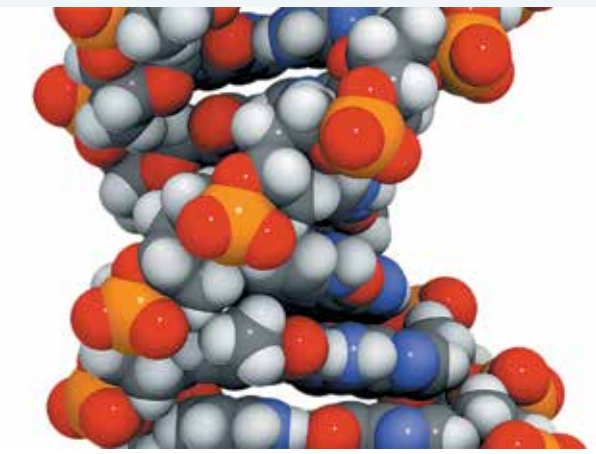
9.1.1 Why learn this?

There are millions of different substances in the world. Some, like water, occur naturally. Others, like paper and plastic, are made in factories. Some substances, like sugar and blood, are made by living things. All substances one have important thing in common; they are all made of the tiny building blocks of matter that we call atoms.

LEARNING SEQUENCE

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DNA, the largest molecule in the human body, contains millions of atoms bonded together. Red spheres indicate oxygen atoms, orange indicate phosphorus, blue indicate nitrogen, grey indicate carbon and white indicate hydrogen.



What's inside?

When you were little, you probably shook and squeezed your birthday presents while they were still wrapped up to work out what was in them before you opened them. For many years, that was what it was like for scientists trying to understand the properties and structure of matter and, in particular, the atom.

1. What sort of information can you infer about a wrapped present by shaking it or squeezing it?
2. Imagine that you have a brightly wrapped box with something in it. Describe the different guessing techniques that you would use to work out what is in the box without opening it.

Trying to work out what atoms are like is not easy when you can't see them.



INVESTIGATION 9.1

How small are the bits that matter?

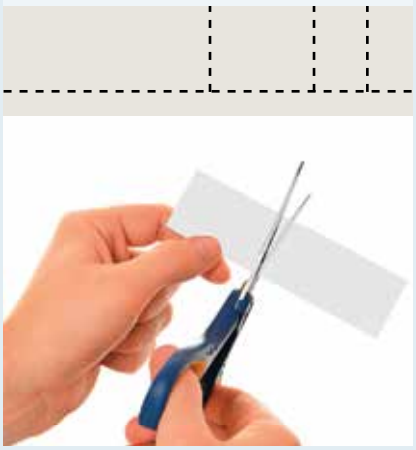
AIM: To investigate division of matter

You will need:

a strip of paper cut from an A4 sheet (about 30 cm long)
pair of scissors
ruler
a lot of patience and care
a sense of humour

- Construct a table like the one below and record the length of the strip of paper.
- Cut the strip of paper in half across the middle. Put one half aside. Measure the length of the other half.
- Cut the measured half in half again. Again, put one half aside and measure and record the length of the other half.
- Before you go any further, predict how many times you will be able to cut the strip in half.
- Continue this process until you can no longer cut the strip in half.

The first three cuts along the strip of paper



How small are the bits?

Number of cuts	Length of strip (approximate)
0	30 cm
1	15 cm
2	7.5 cm (easy?)
3	
4	
5	
6	
7	
8	1 mm (you're doing well to get this far!)
9	
10	
12	
14	
18	1 micron (1 millionth of a metre, one thousandth of a millimetre)
22	
26	
31	The size of a single atom

Discussion

1. How many cuts were you able to make? Was it more or fewer than your prediction?
2. Estimate the number of cuts you would need to make before the strip would be too small to see.
3. Estimate how many cuts you would be able to make if the strip you started with was
   (a) 60 cm long and
   (b) 1 metre long.
4. Do you think that the sharpness of the scissors has an effect on the outcome of this experiment? Explain your answer.

9.2 The history of the atom

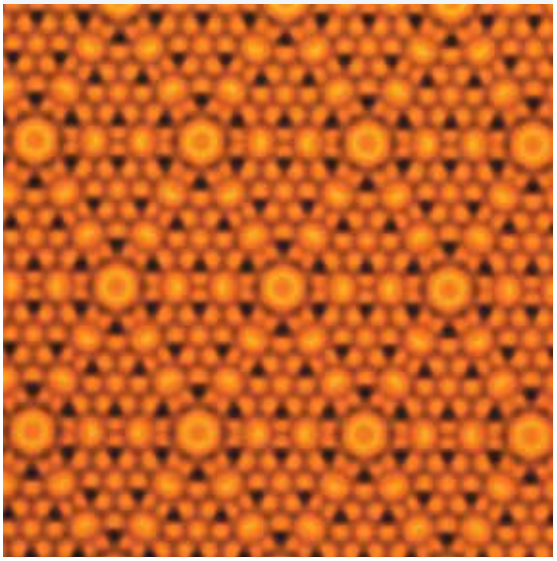
Science as a human endeavour

9.2.1 The atom

All matter is made up of tiny particles that are called **atoms**. In fact, atoms are so tiny that 24 million of the smallest atoms would fit side by side in 1 centimetre, and you could fit 120 000 atoms across the average human hair! They are so small that we have only recently developed the technology that allows us to see them. Here you can see the atoms in a sample of silicon in a photo taken by a tunnelling electron microscope.

While such images provide solid evidence for the existence of atoms, the first recorded theories about these basic building blocks of matter date from thousands of years ago. So how did anyone even know what atoms were back then?

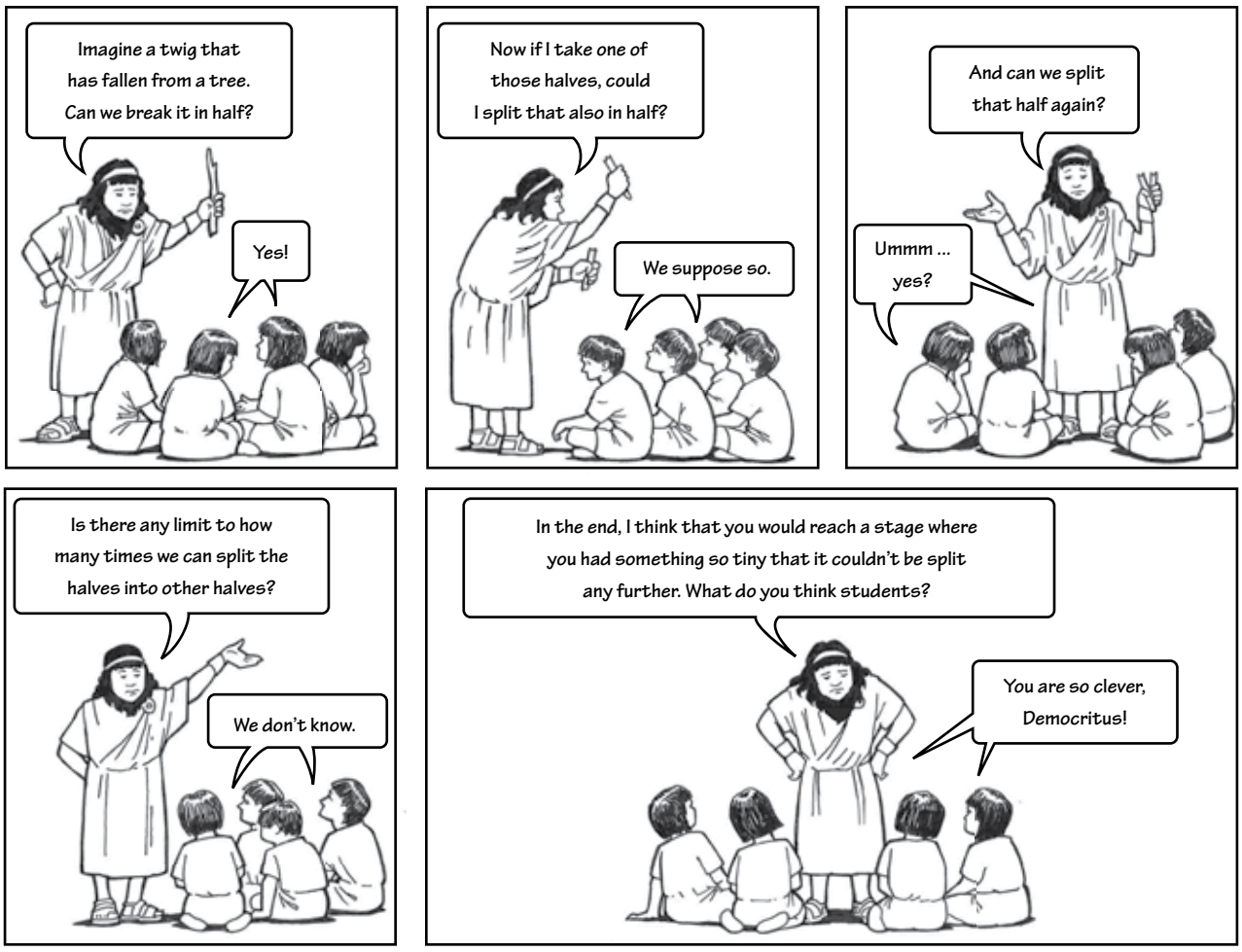
Atoms of silicon



9.2.2 In the beginning …

The idea of the atom started with a thinking exercise that Democritus, a teacher and philosopher living in Greece about 2500 years ago, gave to his students to discuss. Maybe it went something like the story below.

Democritus named these tiniest particles of matter *atomos*, which was the Greek word meaning 'unable to be divided'.



9.2.3 The nineteenth century

Over the next two thousand or so years, people argued over whether atoms actually existed. Even those who believed in the idea of atoms had no real idea of what the atoms actually looked like, and there was a general tendency to regard these mysterious little things as being very small solid balls of stuff, a bit like very tiny marbles. It wasn't until the beginning of the nineteenth century that scientists turned their attention to finding out whether atoms existed and what an atom actually looked like.

John Dalton (1766–1844)

John Dalton is considered to be a pioneer of modern atomic theories. In his 20s and 30s, he experimented extensively on gases to learn more about them and the particles they are made of. Based on his observations, he arrived at a number of important conclusions about matter and atoms, which he presented in 1803.

John Dalton



Dalton's atomic theories

1. Matter is made up of atoms that are indivisible and indestructible.
2. All the atoms of an element are identical.
3. Atoms of different elements have different masses and different chemical properties.
4. Atoms of different elements combine in simple whole numbers to form compounds.
5. Atoms cannot be created or destroyed in a chemical process. When a compound decomposes, the atoms separate but are themselves unchanged.

9.2.4 Twentieth century on ...

JJ Thomson (1856–1940)

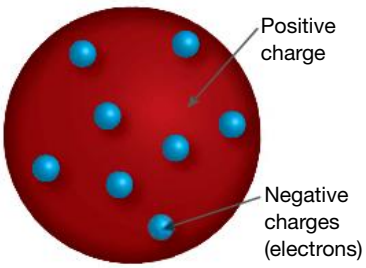
JJ Thomson experimented with electric charges and cathode ray tubes (which were used in the twentieth century to produce pictures in television sets).

He suggested that the glow produced in the tube when electricity was passed through it was due to the movement of small 'corpuscles'. He believed these negatively charged particles to be parts of the atom itself. Further experimentation with gases seemed to suggest that there were both negative and positive charges in the atom. In 1904, he proposed an atomic model in which the atom was a sphere of positive charge that had negative charges (which he called electrons) scattered through it, much like sultanas and plums in a plum pudding. Not surprisingly, this is called the 'plum pudding model' of the atom.

JJ Thomson



The 'plum pudding' model

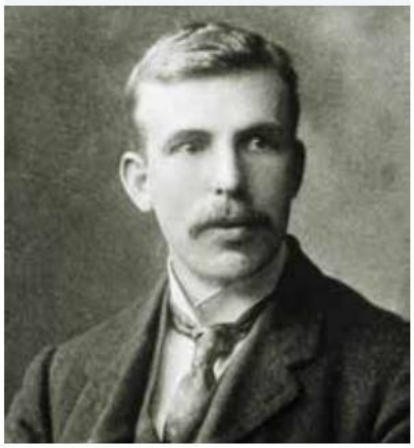


9.2.5 Ernest Rutherford (1871–1937)

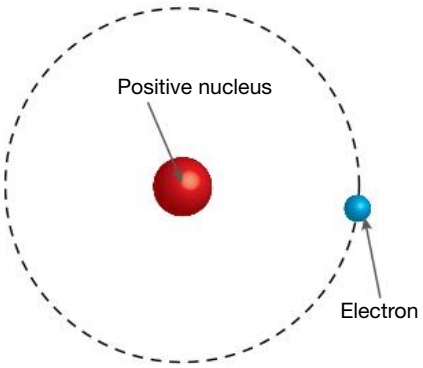
Rutherford's vision of the atom came as the result of experiments he was doing in which he fired positive charges at gold atoms. He found that some of the positive charges could pass right through the atom and, in some cases, the charges bounced right back. If Thomson's model was correct, this would not have happened.

Rutherford proposed a new model of the atom that explained his observations. In this model, the atom was mostly empty space, with all of its positive charge in a clump in the centre (the nucleus). He thought that the electrons moved around the nucleus in fixed orbits, much as planets do around the sun. For this reason, Rutherford's model is sometimes called the 'planetary model' of the atom.

Ernest Rutherford



Rutherford's model of the atom



9.2.6 Niels Bohr (1885–1962)

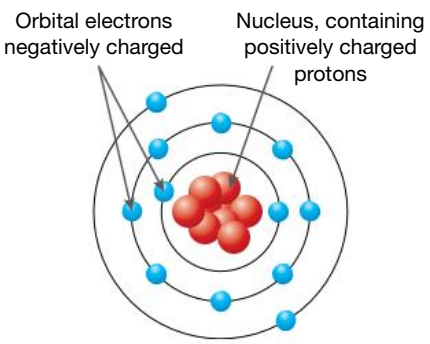
Niels Bohr saw that, if Rutherford's model of the atom was correct, atoms would be very unstable and matter would fall apart all the time, and this didn't happen. Bohr's model of the atom was a lot more complicated but seemed to be consistent with what scientists observed, and it explained a lot of strange things that science, up to then, hadn't been able to explain.

Bohr agreed with Rutherford that the atom was mostly empty space and that most of the mass was in the nucleus where the positive charges were located. However, he proposed that the electrons changed orbits and so they formed electron clouds around the nucleus. In this model, it was impossible to predict exactly where an electron was at a particular time.

Neils Bohr



Bohr's model of the atom



9.2.7 James Chadwick (1891–1974)

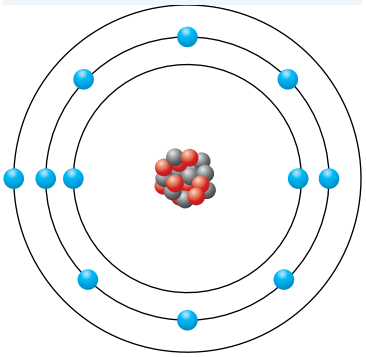
British scientist James Chadwick and Ernest Rutherford noticed in their experiments that the overall mass of the nucleus was much heavier than could be accounted for just by protons alone.

In 1932, Chadwick found proof of the existence of another type of particle in the nucleus — one that was about the same size as the proton but that had no electrical charge. This was the neutron. Chadwick's discovery meant that the Bohr model of the atom had to be adjusted.

James Chadwick



The Chadwick–Bohr model



And now?

At the moment, the Chadwick–Bohr model of the atom is the most consistent with what scientists observe happening in experiments. However, there are still a few things that even this version cannot explain. One day, a new model will be developed to explain what the present model cannot.

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 important idea that Democritus had 2000 years ago about the substances that make up the world.
2. **Recall** where the term 'atom' came from.
3. **Recall** which model of the atom is currently used.
4. **Describe** how Thomson's model of the atom differed from that of Democritus.
5. **Explain** why the model of the atom has changed over the centuries.
6. **Compare** and **contrast** Rutherford's and Bohr's models of the atom.
7. **Explain** why Rutherford's model is called the planetary model.

Think

8. In ancient Greece, scientists developed their theories by discussion rather than by doing formal experiments to test their ideas. **Assess** what problems might arise from using only the ancient Greek approach to science.
9. Why do you think that the neutron was the last of the components of the atom to be discovered?
10. Why has direct observation of the atom been impossible until now?

Create

11. The table below shows when different events in the development of the atomic model occurred. Use these dates to **construct** a ***timeline*** of the events. Remember that you will need to choose an appropriate scale!

Date	Event
Fifth century BC	Democritus proposed the existence of atoms.
1804	Dalton developed his theory of atoms and matter.
1897	JJ Thomson discovered the electron.
1911	Rutherford developed the planetary model of the atom.
1913	Bohr developed a model of the atom.
1919	The proton was discovered.
1932	The neutron was discovered.

Investigate

12. Bohr's model of the atom is also called the quantum model. Find out what a quantum is.
13. Many of the scientists mentioned in Twentieth century won Nobel prizes for their work. Use the library and the internet to discover who won a Nobel prize and for what discoveries.

9.3 The structure of the atom

9.3.1 The nucleus and electrons

We now know that an atom is made up of three types of particles: protons, neutrons and electrons.

Protons and **neutrons** are approximately the same size and are both found in the **nucleus**, or centre, of the atom. While the proton has a positive electric charge, the neutron has no electric charge at all (neutral). As both protons and neutrons are found in the nucleus, you may sometimes see these particles referred to as **nucleons**.

Electrons are nearly 2000 times smaller than protons and carry a negative electric charge. These zoom around the nucleus in constantly changing paths called **orbits**. While we show electrons in diagrams as orbiting quite close to the nucleus, they are relatively far away. To give you an idea of the scale involved, imagine that the nucleus of a hydrogen atom is a tennis ball that you have placed in the middle of a field — the electron would have the diameter of a human hair and be positioned over 2 kilometres away from the tennis ball.

Most of an atom is made up of empty space!!

Balancing act!

The electrons whiz around the nucleus in orbits, some closer to the nucleus than others, but they do not fly off from the atom despite their great speed. This is because the negatively charged electrons are held in their orbit by their electrical attraction to the positively charged protons in the nucleus.

An atom usually has equal numbers of positive protons and negative electrons so it has no overall electric charge.

INVESTIGATION 9.2

Atomic spaces

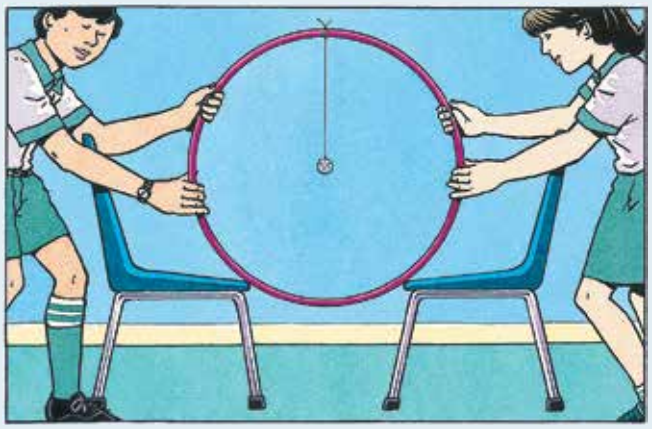
AIM: To demonstrate that most of an atom is empty space

You will need:

1 hula hoop
1 straw

rice grains
cotton thread
table tennis ball
sticky tape
broom and dustpan

- Set up the equipment as shown in the diagram at right.
- From across the room, but within target distance, use the straw as a peashooter to fire rice grains at the table tennis ball.



CAUTION: Ensure that the rice grains are not fired towards any person.

- Count how many grains go right through and how many hit the table tennis ball. (*Note:* Hits to the cotton thread do not count!)
- Use the broom and dustpan to clean up the mess you've left on the floor.

Discussion

1. Construct a bar graph to display your results.
2. Construct a bar graph to show the class results.
3. Which part of the atom does the table tennis ball represent?
4. What does the hula hoop represent?

9.3.2 An array of atoms

So far, 118 different types of atom have been identified. Not all of these atoms are found easily on Earth. Some of them have been observed only under laboratory conditions and have existed for only fractions of a second before breaking up.

The different atoms are made up of different combinations of protons, neutrons and electrons. Only 92 occur naturally. The smallest atom has a single proton in its nucleus, which is orbited by just one electron, while the largest of the naturally occurring atoms has a giant nucleus of 92 protons and 146 neutrons with 92 electrons moving around it.

Structure of an atom — summary

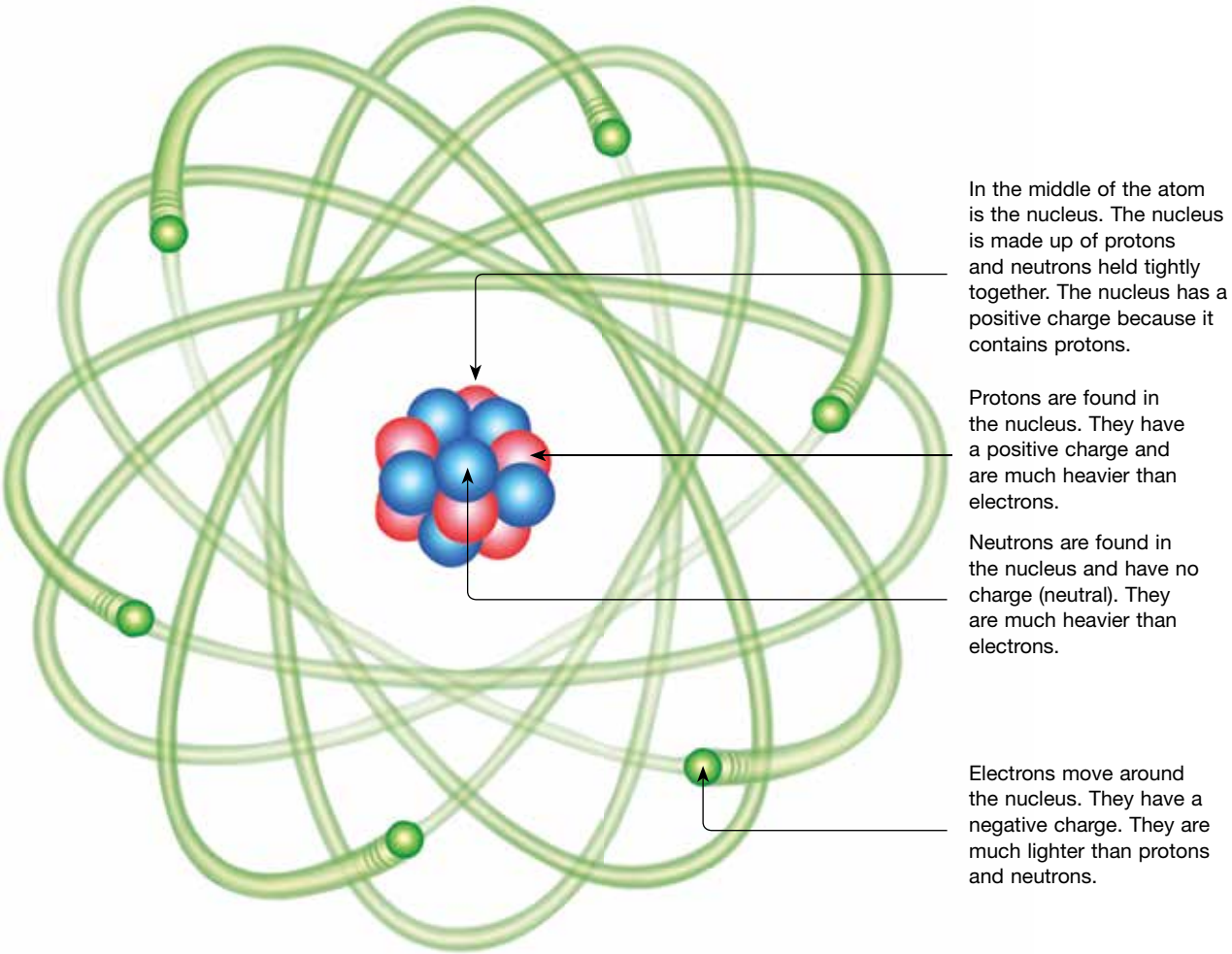
Part of atom	Where found	Relative weight	Charge
Proton	Nucleus	Heavy	Positive
Neutron	Nucleus	Heavy	Neutral (no charge)
Electron	Around nucleus	Light	Negative

HOW ABOUT THAT!

Protons and neutrons are made up of different combinations of even smaller particles called *quarks*. Quarks were first named by the American scientist Murray Gell-Mann in 1964. Gell-Mann named the first three quarks 'up', 'down' and 'strange', with another three, 'bottom', 'top' and 'charm', being identified later.

A proton is made of two 'up' quarks and one 'down' quark, while a neutron is made of two 'down' quarks and one 'up' quark. The word quark can be pronounced to rhyme with either 'mark' or 'cork'.

The models of the atom shown in this topic do not show accurately the relative sizes of electrons, protons and neutrons; electrons are much smaller than those drawn here. Also, the size of the nucleus and the distance between the nucleus and the electrons are not to scale. It is impossible to draw an accurate scale diagram here. The diagram is used only to show how the protons, neutrons and electrons are arranged.



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. **Describe** an atom.
2. Name the three parts of an atom and **explain** where they would be found.
3. **Explain** why electrons do not fly off an atom.
4. **Recall** what makes up most of an atom.

Think

5. If a neutral atom has 12 protons, **calculate** how many electrons it has.
6. What type of electric charge does the nucleus of every atom have?
7. Draw a diagram of an atom that has three protons and one neutron in its nucleus. How many electrons would it have?

Create

8. **Construct** a model of an atom. It should have at least six protons, six neutrons and six electrons. Use any materials that you like. Perhaps try using a bowl of jelly with lollies in it to represent the parts of the atom! Your model should have a key.

Investigate

9. **Investigate** what nanotechnology is and what connection it has with atoms.

9.4 It's elementary!

9.4.1 The alchemists

A page from a fourteenth century alchemy text showing distillation being performed



In ancient Greece, scientific discovery was something that was done by talking and theorising rather than by performing experiments. However, in other parts of the world such as China and the Middle East, people were starting to take a more hands-on approach to unlocking the world's mysteries. These earliest investigations were done very differently from what we now know as modern science and became the basis of alchemy, the ancestor of modern chemistry.

Alchemy has been mentioned in writings dating back thousands of years but it was especially influential in Europe between the twelfth and sixteenth centuries. The alchemists of old were more magicians than scientists though, and their experiments involved not just combining 'pure' substances but also complex combinations of gestures, chanted spells and the drawing of arcane symbols. Experiments were performed only at what they saw as critical times so the alchemists also delved into astrology, believing that certain alignments of stars and planets would help their experiments succeed. The dearest wish of the alchemists was to develop a process (called **transmutation**) that turned base metals, such as lead and copper, into gold, and to concoct an elixir that would grant immortality. Not surprisingly, waving their hands around and chanting was not terribly successful in achieving either of these!

However, the alchemists did discover many important things. While they noticed that some substances such as gold and silver were usually found in their most basic form, others such as carbon could be derived from different substances altogether. By the end of the sixteenth century, they had identified twelve substances that seemed to be 'pure' — gold, iron, silver, sulfur, carbon, lead, mercury, tin, arsenic, bismuth, antimony and copper.

9.4.2 The new science

In about the seventeenth century, people stopped thinking about magic and instead carried out **investigations** based on careful **observations**. These new seekers of knowledge were called **scientists**. They discovered that the twelve pure substances that they knew of could not be broken down further into other substances. Scientists investigated many common everyday substances as well, including salt, air, rocks, water and even urine! They discovered that nearly everything around us could be broken down into other substances. They gave the name **element** to any substance that could not be broken down into other substances. Between 1557 and 1925, another 76 elements were discovered. We now know that 92 elements exist naturally. In recent years scientists working in laboratories have been able to make another 25 artificial elements. In total there are now 118 known elements.

This table from the seventeenth-century text *Opuscula chymica* classifies known substances under the headings *minerae* (minerals), *metalla* (metals), *mineralia* (ores), *salia* (salts), *decomposita* (inorganic materials), *terrae* (oxides), *destillata* (mineral acids), *olea* (oils), *limi* (chalky minerals) and *compositiones* (processes).



9.4.3 Element basics

An element is a substance that contains only one kind of atom. As there are about 118 elements, this means that there are only 118 types of atom that we know of so far. What makes these atoms different from each other is that they are made up of different combinations of protons, neutrons and electrons. It is the specific combination of these smaller particles in the different atoms that gives each element its particular physical and chemical properties.

Just as no two people are the same, neither are any two elements. Elements can be distinguished by looking at such characteristics as their:

- colour
- hardness and brittleness
- melting and boiling points
- density
- state (whether they are solid, liquid or gas at room temperature)
- reaction with acids or other chemicals.

9.4.4 The good, the bad and the ugly!

While many of the elements look pretty similar — dull grey and metallic — they vary enormously in their nature. Bismuth and gold are beautiful to look at and are safe to handle whereas mercury, a liquid metal that has fascinated people for centuries, is toxic and has disastrous effects on human nerve tissue.

Lithium, sodium and potassium are dull grey metals that are so soft that they can be cut into slices with a butter knife. However, they are

Lithium, sodium and potassium are stored in oil to seal them away from air and moisture.



highly dangerous when they come into contact with water — they react so quickly and generate so much heat that they burst explosively into flame. As even the moisture in the air is enough to set them off, they are stored in oil.

Carbon takes on many different forms depending on how its atoms are arranged. It can be dull brittle coal, which can be burned to produce heat; it can be the dull grey 'lead' that runs through the centre of your pencil; or it can glitter like ice when it is in its diamond form.

INVESTIGATION 9.3

Checking out appearances

AIM: To investigate the characteristics of elements

You will need:

samples of chemical elements (such as carbon, sulfur, copper, iron, aluminium and silicon)

- Copy the table below into your notebook.
- Carefully examine each of the elements in the set; look for colour, appearance and hardness.
- Complete the table by filling in the description. One example is completed for you.

Element	State	Description
Hydrogen	Gas	Clear, colourless, explosive

HOW ABOUT THAT!

In days gone by, substances containing mercury were used to make hats. In those days it was not known that mercury is a very poisonous substance. Poisoning by mercury can affect your nervous system and your mind. This sometimes happened to people who made hats and were exposed to mercury for a long time: hence the expression 'mad as a hatter'!

Lewis Carroll's Mad Hatter character in *Alice's Adventures in Wonderland* was mad because mercury was used in the making of hats.



9.4.5 Chemical symbols

In our everyday lives, we tend to have a standard set of shorthand ways of writing common words. For example, we write 'St' for 'street', 'Mr' for 'mister' and 'e.g.' instead of 'for example'. In a similar way, scientists use a standard shorthand way of writing the names of the elements. Each element is represented by either a single capital letter or a capital letter followed by a lowercase letter — these are known as the elements' **chemical symbols**. The chemical symbols of some of the more common elements that you may encounter are shown in the table at the top of the next page.

Element name	Element symbol	Element name	Element symbol
Aluminium	Al	Mercury	Hg
Carbon	C	Nitrogen	N
Copper	Cu	Oxygen	O
Gold	Au	Silicon	Si
Helium	He	Silver	Ag
Hydrogen	H	Sulfur	S
Iron	Fe	Zinc	Zn

Looking at this table, you can see that, in most cases, the chemical symbol was derived from the element's name, using either its first letter (e.g. H = hydrogen, O = oxygen) or the first letter and then the second or third letter (e.g. He = helium, Si = silicon, Zn = zinc). But what about the symbols for gold, copper, mercury, iron and silver?

Interestingly enough, these elements were among the first to have been identified and were usually referred to by their Latin or Greek names by early scholars. As a result, their chemical symbols are based on their classical names: *aurum* (gold), *cuprum* (copper), *hydro argyros* (mercury), *ferrum* (iron) and *argentum* (silver).

9.4.6 Atoms and elements

Elements are identified according to how many protons their atoms have in their nuclei. This value is referred to as the element's **atomic number**. As an atom has the same number of electrons as protons, the atomic number is also equal to the number of electrons that the neutral atom of an element has. The table below shows the atomic numbers of the 10 lightest elements.

Element	Chemical symbol	Atomic number	Number of protons	Number of neutrons	Number of electrons
Hydrogen	H	1	1	0	1
Helium	He	2	2	2	2
Lithium	Li	3	3	4	3
Beryllium	Be	4	4	5	4
Boron	B	5	5	6	5
Carbon	C	6	6	6	6
Nitrogen	N	7	7	7	7
Oxygen	O	8	8	8	8
Fluorine	F	9	9	10	9
Neon	Ne	10	10	10	10

HOW ABOUT THAT!

Hydrogen was made during the big bang that started the universe. The elements with atomic numbers between 2 (helium) and 26 (iron) were created in stars as part of the fusion process. When supermassive stars become supernovae, elements heavier than iron are formed and may be found in the nebulae that are produced as a result. Planetary nebulae such as the Ring Nebula shown here are prime hunting grounds for astrophysicists and astrochemists looking for these heavy elements.



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. **Recall** why sodium and potassium need to be stored under oil.
2. **Describe** the structure of an atom of boron.
3. **Define** the term 'element'.
4. Why do scientists use chemical symbols?
5. State one harmful effect of (a) mercury and (b) sodium.

Think

6. At the entrances to many buildings there are safety signs warning of dangerous chemicals. Give one reason for using chemical symbols on these signs rather than writing the warnings in full.
7. When platinum was discovered, it was assigned the chemical symbol Pt. Why wasn't it given the chemical symbol P?

Investigate

8. The element mercury was known to ancient people and was very important to the alchemists. Find out all you can about this liquid metal. What does its name mean? Where is it found? What has it been used for in the past? What is it used for now? What is the safety procedure if mercury is spilt? Why is mercury dangerous?
9. Many years ago, balloons were filled with hydrogen so that they could float high in the sky. However, hydrogen is no longer used in balloons because it explodes too easily. At fairs, carnivals and in florists' shops, you can often buy colourful gas-filled balloons that fly high into the sky if you let them go. These balloons are filled with another element called helium. **Investigate** who discovered the gas helium, where it was discovered and when.
10. Wolfram, natrium, kalium and stannum are the original names for elements we know under different names. Find out what their modern element names are, when they were discovered, what language their name came from and the chemical symbols that they have been assigned.
11. **Investigate** who decides whether a new element has officially been discovered and what it should be named.
12. Play the **It's elementary! revelation game** in the Resources tab and test your ability to identify common elements from their symbols.

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Try out this interactivity: It's elementary! revelation game (int-0229)

9.5 Grouping elements

9.5.1 The periodic table

During the nineteenth century, as scientists started to find more and more elements, they also started to find that some elements could be grouped together because they had similar chemical or physical properties. Scientists such as Robert Bunsen, John Newlands and Julius Lothar Meyer worked independently over many years to create a system that classified and ordered the elements according to these groups. However, it was not until 1869 that the Russian scientist Dmitri Mendeleev produced the first truly workable version of what we now know as the **periodic table**. While about 60 of the 92 naturally occurring elements had been identified at that time, the discovery since of new elements — some natural and some synthesised — has expanded Mendeleev's original table into the form you see now.

Looking at the common characteristics of the elements of the periodic table, scientists have divided the elements into three main groups — the **metals**, the **non-metals** and the **metalloids**.

9.5.2 Metals

The metals have several features in common:

- They are solid at room temperature, except for mercury, which is a liquid.
- They can be polished to produce a high shine or lustre.
- They are good conductors of electricity and heat.
- They can all be beaten or bent into a variety of shapes — a property called **malleability**.
- They can be made into a wire; we say they are **ductile**.
- They usually melt at high temperatures. (Mercury, which melts at −40 °C, and gallium, which melts at 30 °C, are exceptions to this.)

9.5.3 Non-metals

Only 22 of the elements are non-metals. At room temperature, 11 of them are gases, 10 are solid and one is liquid. The solid non-metals have most of the following features in common:

- They cannot be polished to give a shine like metals; they are usually dull or glassy.
- They are **brittle**, which means they shatter when they are hit.
- They cannot be bent into shape.
- They are usually poor conductors of electricity and heat.
- They usually melt at low temperatures.
- Many of the non-metals are gases at room temperature.

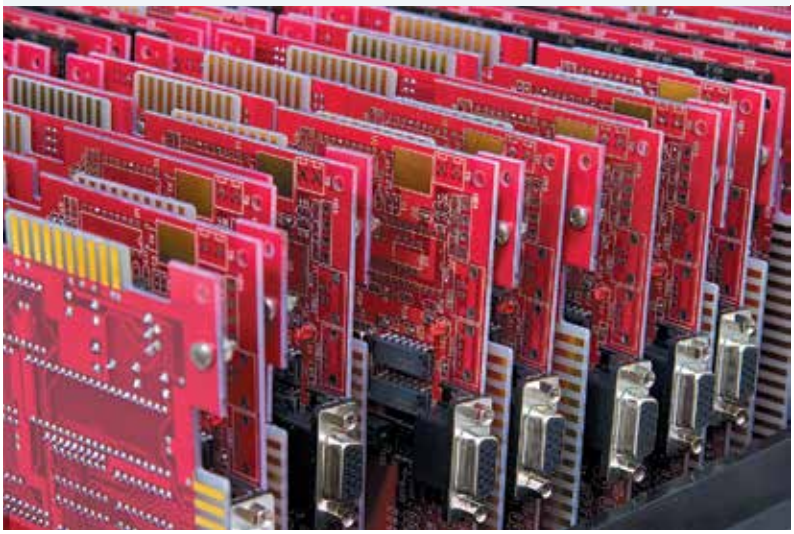
Buckets of sulfur mined from the top of a volcano. Sulfur is a naturally occurring non-metal.



9.5.4 Metalloids

Some of the elements in the non-metal group look like metals. One example is silicon. While it can be polished like a metal, silicon is a poor conductor of heat and electricity and cannot be bent or made into wire. Those elements that have features of both metals and non-metals are called metalloids. There are eight metalloids altogether: boron, silicon, arsenic, germanium, antimony, polonium, astatine and tellurium.

Metalloids are important materials often used in electronic components of computer circuits.



INVESTIGATION 9.4

Looking for similarities

AIM: To determine properties of elements

You will need:

safety glasses
samples of sulfur, zinc, tin, carbon, silicon, copper
steel wool or very fine sandpaper
battery or power pack
wires with alligator clips
light globe

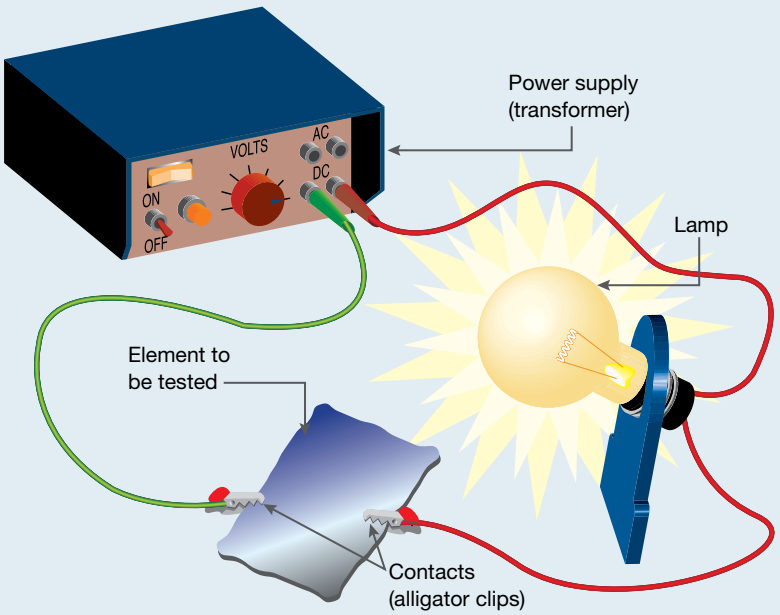
- Make a copy of the table below and use it to record your observations.

Characteristics of some elements

Element	Shiny or dull?	Does it bend?	Does it conduct electricity?
Sulfur			
Zinc			
Tin			
Carbon			
Silicon			
Copper			

- Rub each of the elements with the fine sandpaper and observe whether they are shiny or dull.
- Try to bend the metal.
- Connect the circuit shown in the diagram at right to determine whether electricity passes through each of the elements.

Connect your element sample into this circuit.

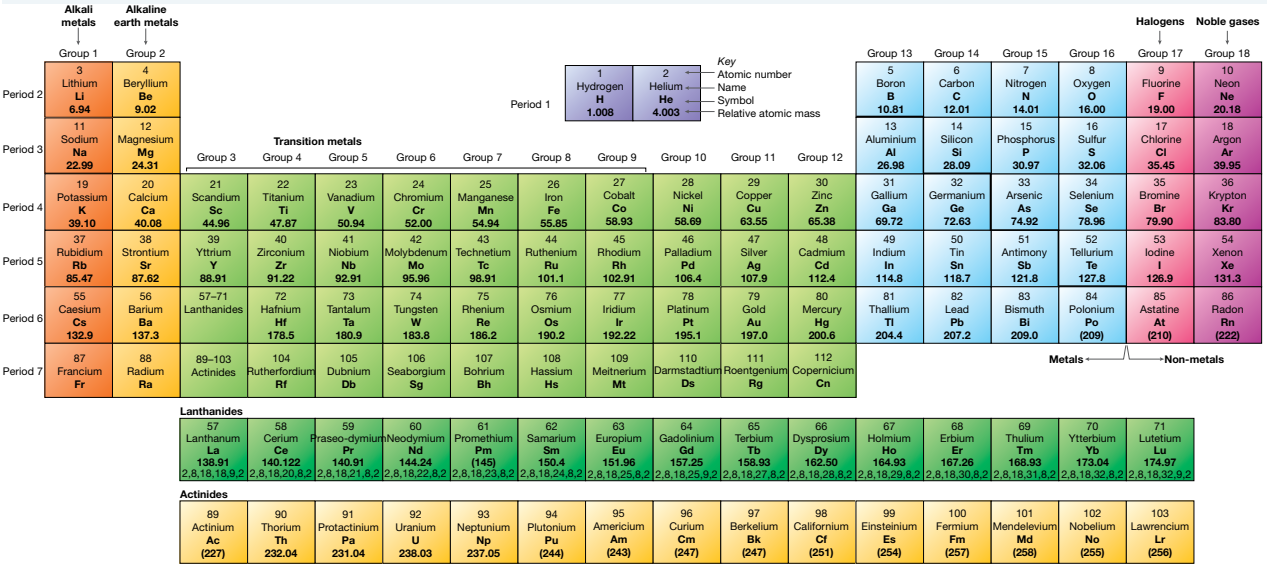


Discussion

1. Which of the six elements have a shiny surface when polished?
2. Which of the six elements do not have a shiny surface when polished?
3. Which of the six elements can be bent?
4. Which of the six elements cannot be bent?
5. Which of the six elements allow electricity to pass through?
6. Which of the six elements do not conduct electricity?
7. Attempt to divide the elements into two groups on the basis of your observations. Suggest names for these two groups.
8. Which of the six elements tested does not seem to fit into either of these two groups?

The periodic table

Elements 1–92 all occur naturally. Those from element 93 onwards have been made in laboratories and are all radioactive. Those for element 104 onwards are not shown in this table.



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. **Recall** four features that metals have in common.
2. **Recall** four features that non-metals have in common.
3. **Define** the term 'metalloid'. List some examples.
4. **Recall** which metal is liquid at room temperature.
5. **Define** the term 'metallic lustre'.
6. **Identify** some scientists who contributed to the development of the periodic table.
7. **State** the chemical symbols and atomic numbers of
   (a) yttrium (b) tungsten (c) xenon
   In each case, **identify** whether it is a metal, non-metal or metalloid.

Think

8. While all metals have similar characteristics, there are also differences between them. List three ways in which metals can differ from each other.
9. Silicon is used in the 'chips' of computer circuits, but it is never used in the connecting wires of electric circuits. **Deduce** why not.

Imagine

10. Imagine that you are a scientist who has discovered what appears to be a new element. It is golden in colour and very shiny. **Propose** experiments to test if it is a metal or non-metal. What results would you expect to get if it is a metal?

Investigate

11. Polonium is a metal discovered by Marie Curie. She also discovered another metal. Find out its name and the important role it played in medicine.

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Complete this digital doc: Worksheet 9.1: The periodic table: atomic structure (doc-12420)

Complete this digital doc: Worksheet 9.2: Metals and non-metals (doc-12421)

9.6 Compounds

9.6.1 What is a compound?

If you have ever seen a gold nugget or watched liquid nitrogen being poured from a canister to freeze things very quickly, then you have seen something quite rare — an actual isolated element. Think about all of the millions of substances in the world. The cotton and wool of your clothes, the paper of your books, the vinyl of your school bag, the plastic bags that you carry the groceries in, the things that you eat, the things that you drink and so on — all of these things are actually made up of different combinations of elements rather than pure elements on their own. In fact, most of the substances that we encounter on Earth are either compounds or mixtures.

9.6.2 Elements and compounds

Most atoms found in nature are joined to atoms of other elements to form a **compound**. While an element contains only one type of atom, a compound is made up of atoms of different elements bonded together. A compound has very different properties from the elements from which it is made. For example, the compound sodium chloride (table salt) is made up of sodium and chlorine atoms bonded together, but it has very different properties from the elements sodium and chlorine when they are on their own.

The elements sodium and chlorine bond to make the compound sodium chloride.



9.6.3 Compounds and mixtures

In topic 5, we looked at the concept of **mixtures**, which are made up of different pure substances mixed together. You will recall that a pure substance is one that is made up of only one type of particle.

It is important to note that compounds and mixtures are not the same thing!

Mixtures can be made up of two or more elements, two or more compounds or a combination of elements and compounds. The substances that make up mixtures can usually be easily separated from each other. When the parts of a mixture are separated, no new substances are formed. Fizzy soft drink is a good example of a mixture. It contains water, gas, sugar and flavours. If you shake the soft drink, the gas bubbles separate from the water and go into the air. You still have the water in the bottle and the gas in the air; they are just not mixed together any more. The parts of the mixture can be separated quite easily. The gas escapes when the lid of the container is opened, and the water can be separated by evaporation, leaving behind sugar and some other substances.

However, when a compound is formed, the atoms of different elements bond together. For example, when the elements iron and sulfur are heated together they form a new compound called iron sulfide. Once formed, it is extremely difficult to separate the iron sulfide into its basic elements again. This is quite different from the relative ease with which we can separate the parts of a mixture.

INVESTIGATION 9.5

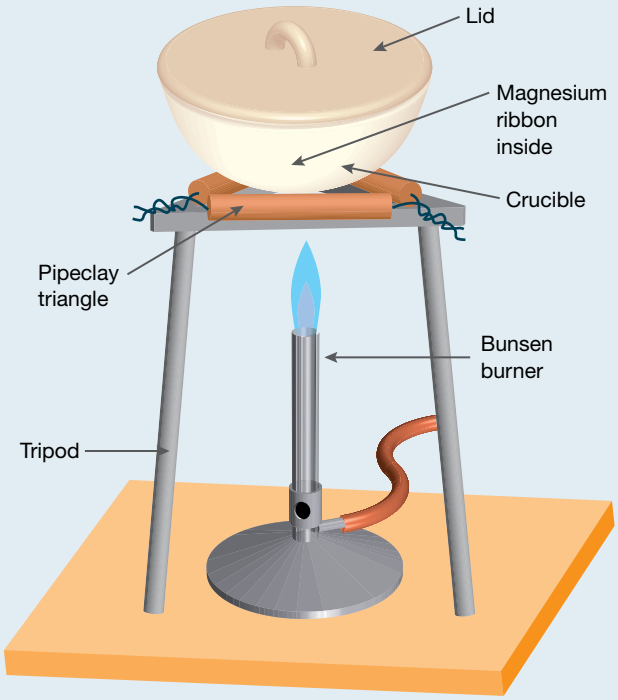
Making a compound from its elements

AIM: To show that a compound has different properties from its elements

You will need:

4–5 cm strip of clean, shiny magnesium ribbon. (It can be coiled to fit in the crucible.)
crucible with lid
pipeclay triangle
tongs
safety glasses
Bunsen burner
heatproof mat
matches

- Examine the piece of magnesium and note its appearance before putting it in the crucible and covering it with the lid.
- Put the crucible on the pipeclay triangle as shown in the diagram.
- Heat the crucible with a strong blue flame, monitoring the reaction by occasionally lifting the lid a little with tongs.
- When all the magnesium ribbon has been changed, turn off the flame and leave the crucible on the tripod to cool.



Discussion

1. Describe the substance in the crucible.
2. Is magnesium an element or a compound? Give a reason for your decision.
3. Magnesium is one of the reactants in this experiment. What is the other reactant?
4. Is the substance remaining in the crucible an element or a compound? What is its name?
5. What is the evidence that a new substance has been made?
6. Apart from observing whether the reaction is complete, give another reason for lifting the lid of the crucible a little with tongs during the burning.

Some common substances

Substance	Type	Composed of:	Scientific name
Gold	Element	Gold	Gold
Diamond	Element	Carbon	Carbon
Water	Compound	Hydrogen and oxygen	Dihydrogen oxide
Table salt	Compound	Sodium and chlorine	Sodium chloride
Brass	Mixture	Copper and zinc	Brass
Soft drink	Mixture	Water, sugar, carbon dioxide and other compounds	
Sea water	Mixture	Water, sodium chloride and other compounds	

9.6.4 Separating compounds

Elements can be separated from the compounds that they make up in a number of ways including:

- passing electricity through the compound
- burning the compound
- mixing the compound with other chemicals such as acids.

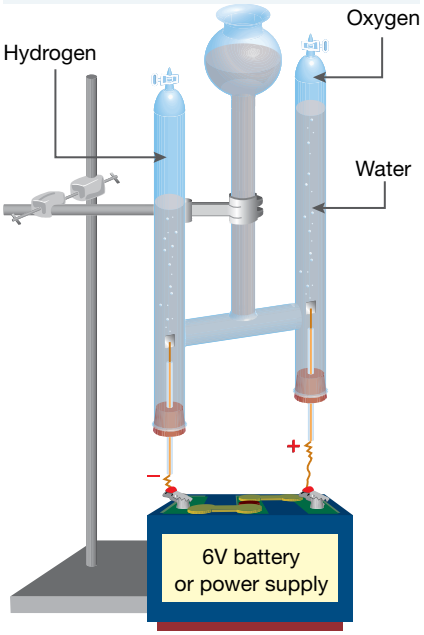
Now, let's look at the first of these methods a bit more closely.

Splitting water

We are surrounded by water. It is in our taps, in our bodies, in the rivers, in the sea and in the air, and it comes down as rain. We wash in it, cook in it and drink it. We cannot live without water. Water is not an element as it can be broken down into simpler substances. The illustration at right shows a piece of apparatus called a **Hofmann voltameter**. Water is poured into the voltameter, which is connected to a battery. The electricity splits the water into the elements that it is made of: **hydrogen** and **oxygen**.

Hydrogen and oxygen are both elements. They are both gases that have no colour and no smell. Hydrogen is a much less dense gas than oxygen. This means that a balloon filled with hydrogen will float up very high, but one filled with oxygen will not.

Water is split in a Hofmann voltameter. The clear gas in the left tube is hydrogen. The gas in the right tube is oxygen. What do you notice about the amounts of hydrogen and oxygen that are produced?



HOW ABOUT THAT!

- Carbon dioxide is the gas that is added to soft drinks to give them their fizz. Solid carbon dioxide, commonly known as 'dry ice', is used to keep things cold at outdoor events.
- The most abundant compound on planet Earth is water (H_2O). Two-thirds of the Earth's surface is covered with water, in which many other compounds (such as salt) are mixed. The compound water is the only substance that is naturally present on Earth in all three states — solid (about three-quarters of the Earth's water is frozen near the North and South Poles and in glaciers), liquid and gas (water vapour in the atmosphere).
- Your own body contains more water than any other substance — about 60 per cent of your body is made up of water. If you think that's a lot, an elephant is 70 per cent water and a tomato is 95 per cent water.

The element hydrogen is present in all acids. By placing a piece of metal in an acid, the hydrogen is forced out. The hydrogen can be collected and tested with a flame.

The element oxygen is present in water, air, rocks and even hair bleach. Oxygen is the gas that all living things need to stay alive. It is also necessary for all substances to burn — even hydrogen does not burn in the absence of oxygen.

When hydrogen gas is burned, it combines with the oxygen in the air to form water. This releases a lot of energy. If large amounts of hydrogen and oxygen are used, enough energy can be released to lift a space rocket!

INVESTIGATION 9.6

Splitting hydrogen from acid

AIM: To separate hydrogen from an acid

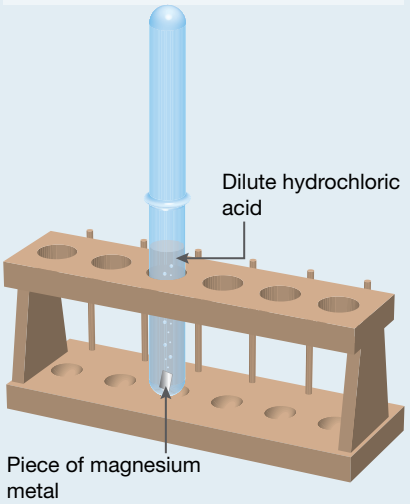
You will need:

safety glasses
2 test tubes and test-tube rack
matches

dilute hydrochloric acid
measuring cylinder
magnesium metal

- Measure 10 mL of hydrochloric acid and pour it into the test tube.
- Add a piece of magnesium and place the second test tube on top of the first, as shown in the diagram at right. Carefully observe what happens.
- After one minute, take the second test tube off the first. While it is still inverted, immediately light the gas in the second test tube with a match.

Collect the hydrogen gas by placing the second test tube over the first.



Discussion

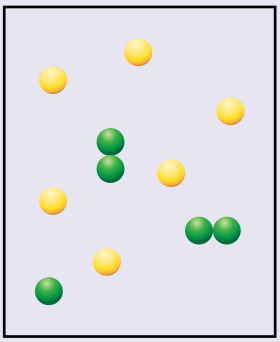
1. Describe what happened in the test tube containing the metal and the acid.
2. What does hydrogen gas look like?
3. What happened when you lit the gas?
4. Look closely at the second test tube. Describe what you see inside it.

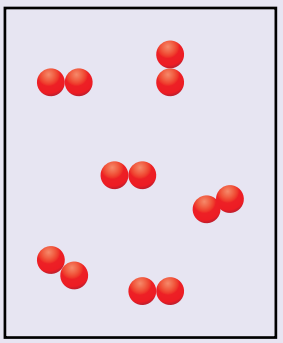
9.6 Exercise: Remember and think

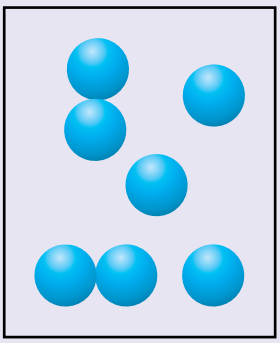
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

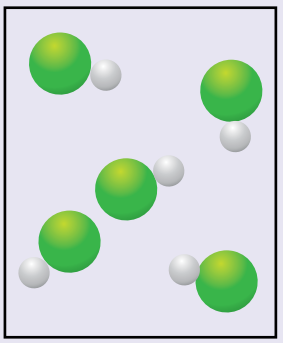
Remember

1. **Explain** the following terms carefully.
   (a) Element
   (b) Compound
   (c) Mixture
2. Give two examples of each type of substance in question 1.
3. **Describe** how compounds differ from elements.
4. **Recall** the important differences between a mixture and a compound.
5. **Recall** three ways in which elements can be separated from their compounds.
6. Fizzy soft drink is a mixture of several compounds. List three of the compounds and suggest how each of them could be separated from the mixture.
7. If atoms are 'bonded' together, **describe** what this means.
8. **Recall** which elements are present in carbon dioxide.


A


B


C


D

Think

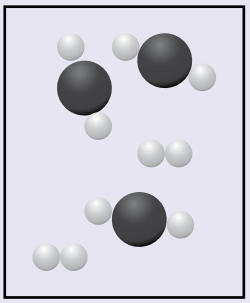
9. **Describe** how you know that water is not simply a mixture of hydrogen and oxygen.
10. Magnesium oxide is a compound of magnesium and oxygen. **Describe** how you know that it is a completely different substance from each of the two elements it is made up of.
11. How can only 92 different elements make millions of different compounds?
12. Which of the diagrams at right represent:
    (a) elements
    (b) compounds
    (c) mixtures?

Investigate

13. Joseph Priestley was one of the first scientists to discover the element oxygen. He also discovered many compounds that are gases. Research and report on the life of Joseph Priestley.

Create

14. **Construct** models of some compounds. You may have to find out how many of each type of atom is in each compound as well as the shape in which the atoms are bonded together.



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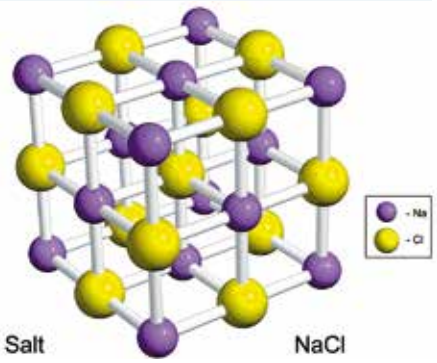
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Complete this digital doc: Worksheet 9.3: The periodic table: elements and symbols (doc-12422)

9.7 Making molecules

9.7.1 Molecules and lattices

Table salt is a lattice made of sodium and chlorine atoms.



Salt NaCl

The naturally occurring elements are the building blocks of everything in our world. The atoms of various elements can be joined in a wide variety of ways to produce many compounds. Elements and compounds can be combined in many ways to make countless mixtures.

Atoms can join, or bond, in many different ways. In some substances, atoms are joined in groups called **molecules**. For example, in oxygen gas, oxygen atoms are joined in groups of two. Atoms in nitrogen and chlorine gas also travel in pairs. In the compound carbon dioxide, one carbon and two oxygen atoms are bonded together in every molecule. Atoms can join to form small or large molecules of many different shapes.

Some compounds are not made up of molecules. Instead the atoms bond by forming structures called **lattices**. Sodium bonds to chlorine, which bonds to sodium and so on. Common table salt is an example of a substance that is bonded in this way.

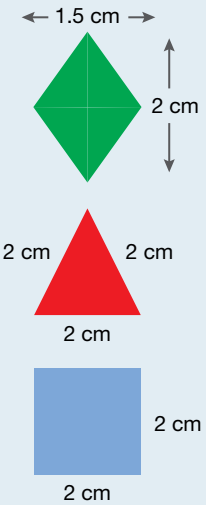
INVESTIGATION 9.7

Mix 'n' match
AIM: To explore the variety of compounds that can be formed from just three elements

You will need:
green, red and blue sheets of paper
scissors, pencil, ruler
1 large sheet of cartridge paper

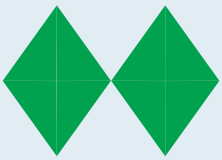
- Cut out 25 diamonds, each 2 cm long and 1.5 cm wide, from the green sheet of paper.
- Cut out 30 equilateral triangles, with each side 2 cm, from the red sheet of paper.
- Cut out 15 squares, with each side 2 cm, from the blue sheet of paper.
- Imagine that different types of atoms are represented by particular shapes:
  a blue square = carbon
  a green diamond = oxygen
  a red triangle = hydrogen
  and that, by placing them side by side on the sheet of paper, you are joining them.

Cut these shapes from coloured paper.



- Place two green diamonds next to each other on the sheet. This represents the element oxygen, as shown in the following diagram.
- Place one blue square on the sheet between two green diamonds. This represents the compound carbon dioxide. Label it with its name and symbol.
- Represent and label the following substances:
  (a) water, which contains 1 oxygen and 2 hydrogen atoms
  (b) methane (natural gas), which contains 1 carbon and 4 hydrogen atoms
  (c) benzene (in petrol), which contains 6 carbon and 6 hydrogen atoms
  (d) glucose (sugar), which contains 6 carbon, 12 hydrogen and 6 oxygen atoms
  (e) hydrogen peroxide (found in hair bleach), which contains 2 oxygen atoms and 2 hydrogen atoms.

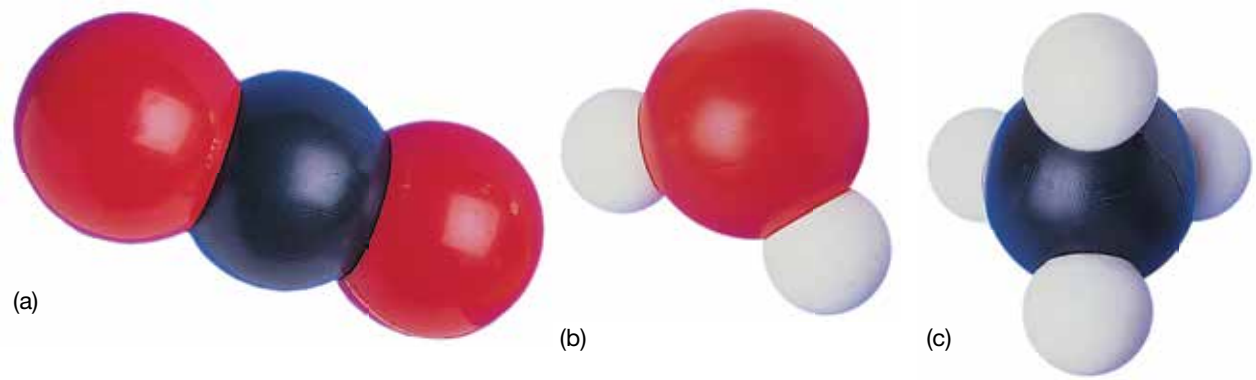
A green diamond represents an atom of oxygen. Together, two diamonds represent a molecule of oxygen.



Discussion

1. Which of these compounds contain only hydrogen and carbon atoms? In what ways are these two substances different from each other?
2. Which of the compounds contain only oxygen and hydrogen? Do these compounds have the same characteristics?
3. Think about the appearance of the compound sugar. How does it differ in appearance from the elements that it is made of?

Molecules of (a) carbon dioxide, (b) water and (c) methane. These models are called space-filling models; they show the relative sizes of the centre-to-centre distances between the atoms. These models are useful in showing the dimensions of a molecule but don't show the bonds involved.



(a) (b) (c)

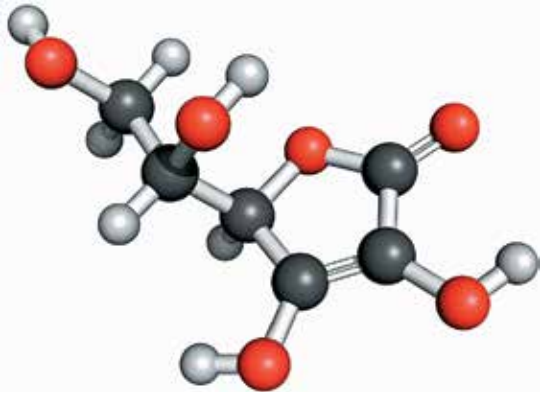
HOW ABOUT THAT!

- The 17th century French philosopher René Descartes was the first person to represent a water molecule as being made up of one oxygen atom connected to two hydrogen atoms. He didn't know about the way they were bonded together, however. He envisaged that the atoms in a molecule were connected by a sort of hook-and-eye arrangement, with the eyes being attached to the oxygen atom and the hooks being on the hydrogen atoms. Sort of like atomic velcro!
- You can make an educated guess about what state of matter a substance is found in at room temperature by looking at the size of the molecule that they usually form. Small molecules made of only a few atoms, such as carbon dioxide and methane, are usually gases. On the other hand, large molecules are usually found in the form of solids at room temperature.

9.7.2 Ball-and-stick models of molecules

Ball-and-stick systems are used to represent molecules as drawings in 2D or as 3D kits. The atoms are represented as balls and the bonds between the atoms are represented by the sticks that join the balls together. Traditionally, the balls are coloured to represent particular atoms: white (hydrogen), black (carbon), red (oxygen), yellow (sulfur), green (chlorine) and blue (nitrogen).

A ball-and-stick model of a molecule of ascorbic acid (vitamin C)



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. What is a molecule? Name two compounds that are made up of molecules.
2. Are all compounds made up of molecules? **Explain**.
3. Name four elements that are made up of molecules.
4. Complete the table below for the molecules mentioned above. The first entry has been done as an example.

Substance	Number and types of atom	State at room temperature
Carbon dioxide	1 carbon 2 oxygen	Gas
Water		
Ascorbic acid		
Methane		

5. In a ball-and-stick model of a molecule, what does the stick represent?

Think

6. Draw a diagram to represent each of these molecules. Use the ball-and-stick model of ascorbic acid as a guide to presenting your diagrams.
   (a) Nitrogen gas (two nitrogen atoms joined together)
   (b) Carbon dioxide.
7. A particular molecule is made up of 12 carbon, 22 hydrogen and 11 oxygen atoms. What state of matter is this substance most likely to be found in at room temperature? **Explain** your answer.

Investigate

8. Find out who developed the ball-and-stick system for representing the molecule and where and when they first used it.
9. What is the largest molecule presently known? How many atoms does it contain and what elements?
10. Complete the **Making molecules** interactivity in the Resources tab by creating the correct model of the molecule as each chemical formula appears.

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Complete this digital doc: Worksheet 9.4: Making compounds (doc-12423)

Try out this interactivity: Making molecules (int-0228)

9.8 Polymers

9.8.1 Polymers and plastics

If you were packing things to keep you warm on a trip to a cold climate, soft-drink bottles wouldn't be the first things you'd think of, would you? Yet windproof, polar fleece jackets and trousers are made from the plastic recycled from soft-drink bottles. The plastic can be reformed and recycled because of the special structure of its molecules.

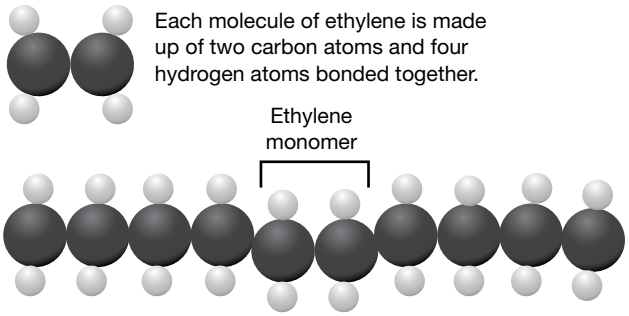
Polymers

Polymers are long molecules made up of many smaller identical molecules (called **monomers**) bonded together. The term 'polymer' comes from two ancient Greek words: *poly* meaning 'many' and *meros* meaning 'parts'. Most polymers are made up of chains containing carbon atoms.

Plastics are synthetic polymers. Polyethylene, for example, is a polymer that is used to make plastic bags. It is made up of thousands of ethylene molecules chemically linked together in a long chain.

Cotton and rubber are examples of natural polymers. Although scientists first developed polymers in laboratories in the 1800s, it was not until after World War II that most of the modern polymers were invented. Modern polymers are used in food wrapping, paint, plastic glass, polystyrene foam for packaging and cups, banknotes, cases for electronic appliances such as computers and televisions, clothing, glues, shopping bags, sports equipment and even tea bags!

A polymer is made up of smaller units called monomers bonded together.



The polymer polyethylene is made of thousands of ethylene monomers all bonded together in long chains.

9.8.2 Natural and synthetic polymers

Synthetic polymers

These are manufactured by using chemical processes. They are often referred to as just plastics.

The polymer **polyvinyl chloride (PVC)** is made up of monomers of vinyl. It can be made into sewerage and drainage pipes that are strong, light and non-corrosive.



Polyethylene is used to make plastic bags, soft-drink bottles and fabrics such as polar fleece.



When spun into long threads, **nylon** (or polyamide) can be made into ropes, guitar strings, pantihose and fabric. It can also be made into a more rigid form for machine parts.



Natural polymers

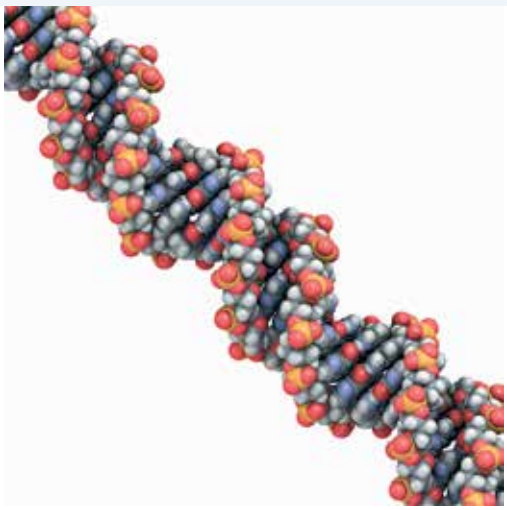
The **silk** polymers that are woven to form beautiful fabric come from the cocoons made by the silkworm.



Forty per cent of the wood in trees is made up of the polymer **cellulose**. This cellulose can be used to make paper. Cellulose is made up of monomers of simple sugars.



The DNA molecule is made up of two long polymers of **nucleic acid** intertwined to form a helix shape. DNA is found in every nucleated cell of every organism and is made up of protein building blocks.



Cotton plants are also a source of cellulose polymer. The fluffy, fibrous boll is 90 per cent cellulose!



Fingernails, toenails and hair are all made of a polymer called **keratin**, which is formed from protein molecules.



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. What is the difference between a polymer and a monomer?
2. What are plastics?
3. Where do you find the polymer keratin?

Think

4. What is the difference between a synthetic polymer and a natural polymer? How are they similar? Give two examples of each.
5. Synthetic polymer names are usually based on the names of the monomers of which they are made. For example, polyethylene is made up of monomers of ethylene. **Deduce** the names of the monomers for these polymers.
   (a) Polyester (b) Polystyrene (c) Polypropylene

Investigate

6. Bakelite was the first artificial polymer to be manufactured on a large scale. Find out who invented it, what it was made from and what it was used for.
7. One well-known property of polymers is that they do not conduct electricity. However, in 2000, the Nobel prize in chemistry was awarded to scientists who found a way to make a polymer do so. Find out how this was achieved and what the discovery will be used for.
8. Australia has led the way in the production of polymer money. Find out all you can about how these banknotes are made.
9. How are plastic bottles turned into cold weather fabrics? **Investigate** the process by which polar fleece fabric is made. Also, find out where and when it was invented.

9.9 Mixed-up metals

9.9.1 Alloys

Not everyone is good at sport; not everybody can draw; we certainly know that all people are not the same height! Just as people are different, so are the pure metals. And just as you wouldn't pick someone who cannot sing to take the starring role in the school musical, you cannot pick any old metal to do a particular job. For example, iron is very strong so it is great for building bridges, but you wouldn't make a bracelet from it. Gold is good in jewellery because of its lustre and its rarity (which makes it very valuable). However, it is very soft so it cannot be used for jobs that need a strong metal. So, what happens when you need a metal that has a combination of properties that no pure metal has?

An **alloy** is a mixture of pure metals that has properties that the pure metals on their own do not have. They are made by melting the metals that need to be combined and then mixing them together, much as you do with milk and melted butter when you make a sauce. Remember, though, that the atoms of the original metals do not combine with each other to form molecules and an alloy is not the same as a compound.

The properties of an alloy can be adjusted by using different proportions of the metals that make them.

9.9.2 Meteoric iron

The earliest known alloy used by humans actually fell from the sky. About 8 per cent of meteorites that fall to Earth are composed of a naturally occurring alloy of iron and nickel. The metal salvaged from these 'fallen stars' was believed to have mystic properties; it not only had fallen from the heavens but also could be formed into weapons, tools and utensils that were harder and stronger than any other materials that humans used at the time. The earliest meteoric iron tools found date back as far as 4000 BCE — long before the start of the iron age. A dagger made from meteoric iron was found in the tomb of Tutankhamen,

and some historians believe that the mystic weapons Excalibur and Durendal (the sword of Roland) were made from fallen iron meteorites.

A section of iron meteorite found in California. The markings on the surface are called Widmanstatten patterns.



9.9.3 Bronze

Bronze is believed to be the first alloy purposely made by humans and is believed to have originated in ancient Mesopotamia, an empire that covered much of what is today the Middle East. It is a mixture of copper and tin, and it has been used for nearly 5000 years to make weapons, statues, coins and bells. It is very strong and durable; it is much stronger than either copper or tin. Many of the large statues that you see in public places, such as the statue of Queen Victoria outside the Queen Victoria Building (QVB) in Sydney, are made of bronze.

While bronze is deep brown in colour to start with, it can develop a whitish green coating, called **verdigris**, on it when it has been exposed to air and moisture.

Bronze statue of Queen Victoria (showing verdigris) outside the Queen Victoria Building in Sydney



9.9.4 Brass

Brass — a mixture of copper and zinc — has been used by humans for nearly as long as bronze; it is prized for its hardness, resistance to corrosion and gold-like appearance. Even today, brass is commonly used for fittings on boats because it is resistant to the corrosion that other metals suffer when exposed to salt water for a long time. Musical instruments, such as tubas, trumpets and trombones, that you find in the brass section of an orchestra are made of this alloy because it is easily shaped and moulded and it has excellent acoustic (sound) properties.

9.9.5 Steel

While steel has been produced for thousands of years, its production was very much a matter of trial and error until the seventeenth century. Steel is the term generally used for an alloy of iron and carbon. When different proportions of carbon are added to iron, they form different grades of steel. Steel contains between 0.2 and 2 per cent carbon. The more carbon there is in steel, the stronger and harder it is. However, more carbon also makes steel more brittle. Early makers of steel had little control over the carbon content so, while they sometimes produced swords and armour of high quality, they were just as likely to produce items that snapped when first used!

Once the production of steel was made more efficient, it quickly became cheaper and easier to fabricate. Skyscrapers were made possible only by the production of large quantities of good-quality steel; today, it is the most common alloy in use with over one billion tons being produced every year worldwide.

Alloy	Made of …	Used for making …
Bronze	Copper, tin	Statues, coins
Brass	Copper, zinc	Engine parts, decorative fittings, musical instruments
Steel	Iron, carbon	Bridges, buildings, car parts
Stainless steel	Iron, nickel, chromium	Cutlery, kitchen fittings
Rose gold	Gold, copper	Jewellery
Solder	Lead, tin	Joins for electrical components

HOW ABOUT THAT!

The heating, mixing, pouring and cooling of steel all affect the strength of the final product. It has been theorised that one of the reasons that an iceberg was able to tear such a large hole in the side of the *Titanic* was because the steel used had too high a carbon content, making it very brittle in the icy Atlantic waters.

9.9 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. **Define** the term 'alloy'.
2. **Explain** why alloys are used instead of pure metals for some purposes.
3. **Identify** the alloy in the table above that contains a non-metal. What is the non-metal?
4. **Describe** how an alloy is different from a compound.
5. How does bronze differ from brass?

Think

6. Lead melts at 327 °C and tin melts at 232 °C, yet the melting point of solder (an alloy of lead and tin) is 183 °C. **Explain** this surprising fact.
7. **Describe** what properties alloy wheels have that could not be provided by a pure metal.
8. Draw a picture of the atoms in a sample of brass. Provide a key that **identifies** the atoms present.
9. Why is steel not used for the frames of racing bicycles?

Investigate

10. Although some Australian coins look like silver and gold, they are actually made of different alloys. **Investigate** how our coins are made and what metals are used to make them.
11. What was the bronze age and when did it occur? Research this time period and find out what life was like back then.
12. Is it possible to separate the metals of an alloy once they have been mixed? **Investigate** this using your library and the internet.

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Complete this digital doc: Worksheet 9.5: Alloys (doc-12424)

9.10 Carbon — the stuff of life

9.10.1 That's made of carbon?

Carbon is a most amazing element. It is found naturally in at least three different forms. One form is **diamond**, another is **graphite** (the 'lead' in lead pencils), and the third is called amorphous carbon (coal, charcoal and soot). The three forms are different from each other because the carbon atoms are joined in different ways. Diamond, graphite and amorphous carbon are called carbon **allotropes**. Allotropes of an element have different appearances and properties due to differences in their molecular structures.

It is possible to change one form into another. Amorphous carbon can be changed to graphite by mixing it with sand and heating the mixture to about 2000 °C. To change graphite to diamonds, huge pressures and very high temperatures are needed. This occurs deep within the Earth over long periods of time, and can also be done in special factories.

Diamonds do not melt! When heated they change straight from solid to gas. This happens at about 3500 °C. Diamond is the hardest substance known and is used to make drill tips and cutting tools.

Carbon is found combined with other elements in a huge range of compounds. No other element forms as many different compounds as carbon. Carbon is found in everything from the skin of an elephant to paint on the walls!

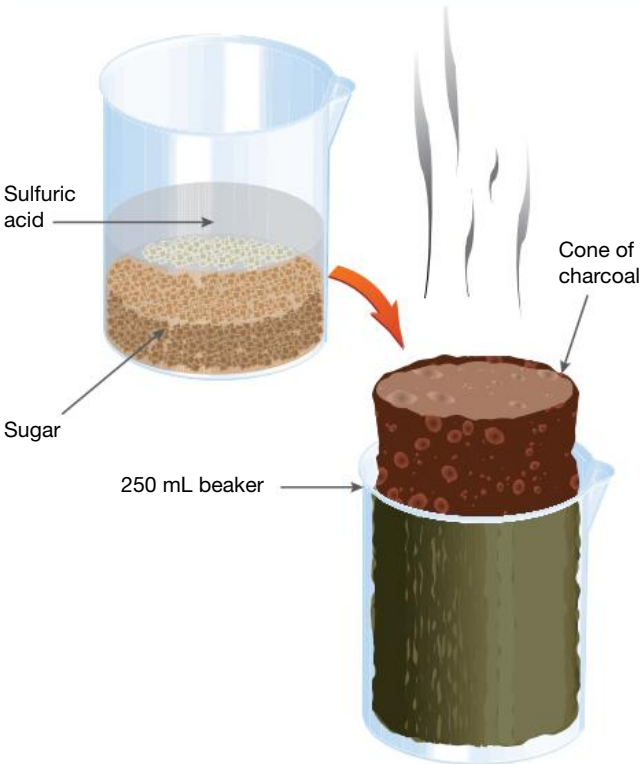
The naturally occurring three forms of carbon: diamond, graphite and amorphous carbon



9.10.2 Finding carbon

Carbon was one of the first elements identified by the alchemists. Concentrated sulfuric acid can be used to detect the presence of carbon in sugar. This acid is too dangerous for you to use in the classroom, but the diagram at right shows what happens when sulfuric acid is poured over some sugar in a beaker. The sulfuric acid changes the other elements in sugar into different substances, leaving the carbon behind as charcoal.

When sulfuric acid is added to sugar, the beaker gets very hot, steam escapes and the element carbon is left behind.



HOW ABOUT THAT!

A company based in Victoria uses the ashes of dead people to make diamonds for clients who want a permanent memento of their loved ones. To create the diamonds, the ashes are prepared and then placed under high temperature and high pressure to crystallise for between six and twelve months, depending on the size of the diamond wanted. The diamonds — which can also be coloured yellow, red, green or blue — can then be cut and polished into the desired shape and even inscribed with a laser before being set into jewellery.

INVESTIGATION 9.8

It's elementary, my dear Watson!

AIM: To investigate whether carbon is present in some common substances

You will need:

safety glasses
Bunsen burner, heatproof mat and matches
metal tongs
small samples of substances to investigate (such as woollen cloth, cotton wool, sugar cube, wood, bread, peanut, steel wool, glass, paper and aluminium foil)

- The early scientists were investigators, working methodically to find an answer to a mystery, a bit like the famous detective Sherlock Holmes. The scientists searched for elements in everyday substances. Your task in this experiment is to find out if the element carbon is present in some common substances. Earlier investigators discovered that carbon can be detected if a substance turns black when it is burnt.
- Your teacher may allow you to burn some plastic in the fumehood.

CAUTION: Burning plastics produce poisonous fumes. A fume cupboard must be used.

- Hold a small piece of the substance you are going to test in the metal tongs.
- Put it in the blue flame of the Bunsen burner.
- When it catches alight, take it out of the flame and, keeping it above the heatproof mat, allow it to burn slowly. Does it turn black?
- Draw up a table like the one below and record your observations.

Substance	Observations	Is carbon present?
Wood		
Cotton wool		

Discussion

1. In which of the substances tested is carbon present?
2. Can you be sure that, if the substance went black, carbon was present? Give a reason for your answer.
3. Can you be sure, if a substance didn't go black, that it didn't contain carbon?
4. Give a reason for your answer.

9.10.3 The chemistry of life

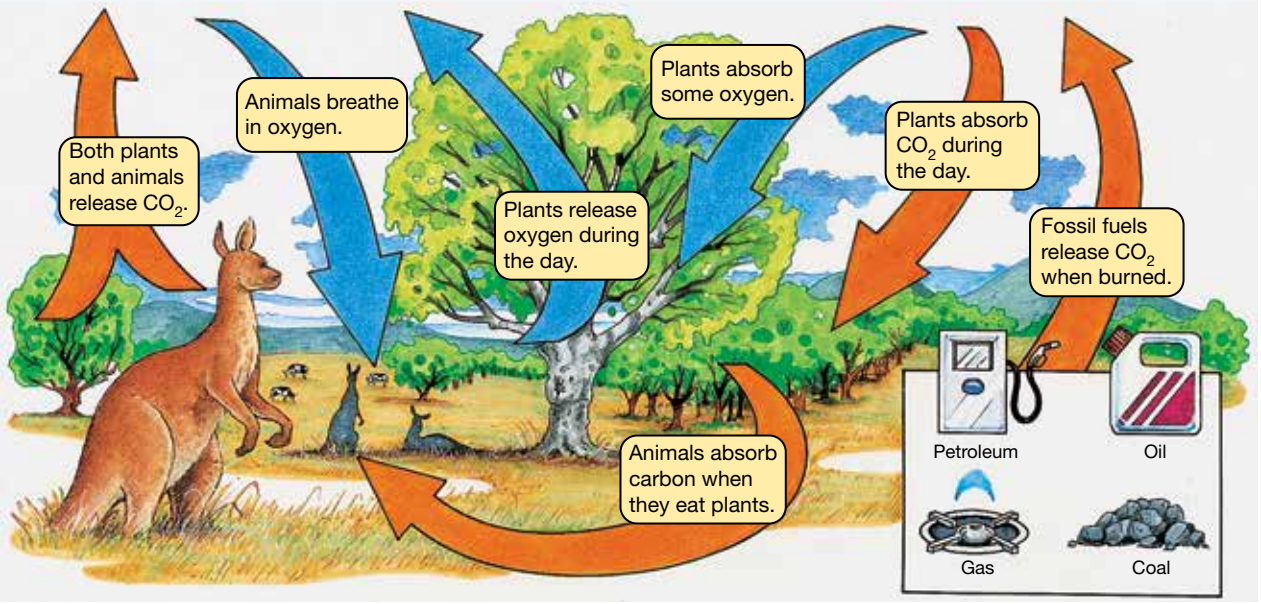
All living things are made up of compounds including proteins, fats and carbohydrates. The main element in these compounds is carbon. Carbon is not found only in living things. It is also found in the air in carbon dioxide and under the sea in limestone. The carbon atoms in carbon dioxide were once carbon atoms in living things. The carbon atoms in living things will eventually become carbon atoms in the air or carbon atoms in limestone under the sea. The illustration at the top of the next page shows how nature constantly recycles carbon atoms.

Plants take in carbon dioxide through their leaves and, in a process known as **photosynthesis**, use the carbon dioxide and water to make starch. Starch is a compound made up of carbon, hydrogen and oxygen atoms. Plants use the starch to make other substances and for energy to grow. Animals eat plants or plant-eating animals. The carbon atoms then become part of the animals' bodies.

Carbon atoms in the bodies of living things return to the air in several ways: **respiration**, **decomposition** and **burning**.

- Respiration is a process that occurs in the cells of every living thing, from a microscopic water plant to a humpback whale. Respiration releases energy and produces carbon dioxide. The carbon dioxide released by the cells in your body is taken by your blood to your lungs. The carbon dioxide that you breathe out contains carbon atoms that were once part of your body.

The flow of carbon atoms through the environment



- Decomposition is what happens when plant or animal material breaks down, such as in a compost heap or after something is buried. Microscopic living creatures called **decomposers** absorb some of the substances in the dead material and release carbon dioxide into the air by respiration.
- When substances containing carbon are burned, carbon dioxide is released. Coal, natural gas and oil are all **fuels** formed from living things, and contain carbon atoms. When these fuels are burned in homes, cars, factories and power stations, carbon dioxide is released into the air. Bushfires also release carbon dioxide back to the air.

9.10 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. **Recall** and describe three different forms of the element carbon.
2. **Recall** where plants get the carbon from that they need to make starch.
3. **Describe** three ways in which carbon can return to the atmosphere.
4. **Recall** where respiration takes place.
5. **Define** the term 'allotrope'.
6. **Define** the term 'decomposition'.
7. What is amorphous carbon and how does it differ from graphite and diamond?

Think

8. **Describe** how animals obtain carbon.
9. Where does the carbon come from to form limestone at the bottom of the sea?
10. The amount of carbon dioxide in the Earth's atmosphere is increasing. **Deduce** why this is happening.
11. When sulfuric acid (chemical formula H_2SO_4) is added to sugar (chemical formula $C_{12}H_{22}O_{11}$), it produces steam (H_2O) and a large amount of a black, cindery solid.
    (a) **Identify** the elements present in
    (i) sulfuric acid, (ii) sugar, (iii) steam.
    (b) Given that none of the elements has vanished, **deduce** which elements are present in the black solid.
    (c) Sulfur is generally a bright yellow powder. **Deduce** why it is not readily seen in the black solid.
12. Would it be possible for life to continue on Earth without plant life? **Explain** your answer.

Using data

13. Many different materials are used to provide heating. The table at right shows how much carbon there is in each of them. The last column indicates how much heat (in therms) that 50 kg of that material provides.
    (a) Draw a bar graph showing the percentage carbon content of each material.
    (b) **Deduce** which is the best material to use to provide heat.
    (c) Does the table indicate any relationship between the amount of carbon in a material and the amount of heat that it provides? **Explain** your answer clearly.

Material	Carbon content (%)	Heat production (therms)
Wood	11	8.5
Peat	10	10
Lignite	30	12
Black coal	80	17
Brown coal	73	14
Natural graphite	90	18.5

Investigate

14. **Investigate** the greenhouse effect. How is it related to carbon dioxide?
15. Fuels may be solids, liquids or gases. Search the internet or use a library to find as many examples as possible of solid, liquid and gas fuels, and complete a table like the one at right.
16. Fullerines and buckyballs are special allotropes of carbon. Research what makes these carbon lattices so special.

	State		
	Solid	Liquid	Gas
Examples			
Uses			
Advantages			
Disadvantages			

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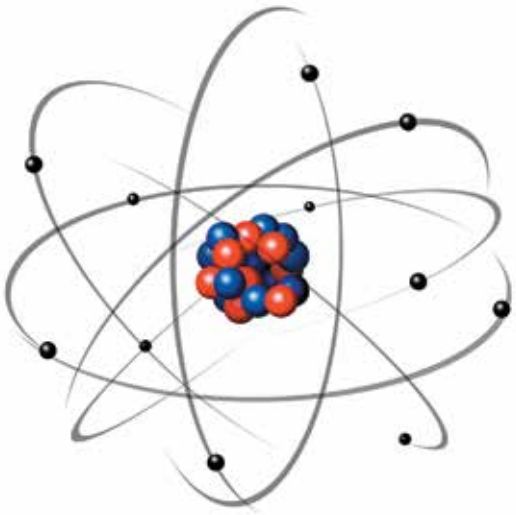
Complete this digital doc: Worksheet 9.6: Carbon (doc-12425)

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9.11 Project: Science TV

Scenario

In the media world, programs that combine entertainment and education are known as 'edutainment'. With the success of edutainment programs such as *Mythbusters* (SBS), *Scope* (Network 10) and *The FundaMentals* (ABC), it seems that science is attracting a bigger share of the television market than many network executives would have expected. Now, your local TV network — Channel 55 — has decided to jump on the 'science as edutainment' bandwagon and has announced that it will be developing a program called *Science TV* next year.



To make *Science TV* more appealing to a younger audience, the developing executives of the program want it to be presented by a team of school students, who will do all of the introductions, explanations and experiments for each of

the segments. It is important that the right team of students is found or the program will be canned after only a few episodes, so Channel 55 has announced that it is accepting online audition files from groups of students who think they have what it takes to be the *Science TV* stars.

Your task

Your group is going to put together a video submission that you could send to the Channel 55 developers to showcase how suitable you would be as the stars of *Science TV*.

The guidelines for the video submission from the Channel 55 website are as follows.

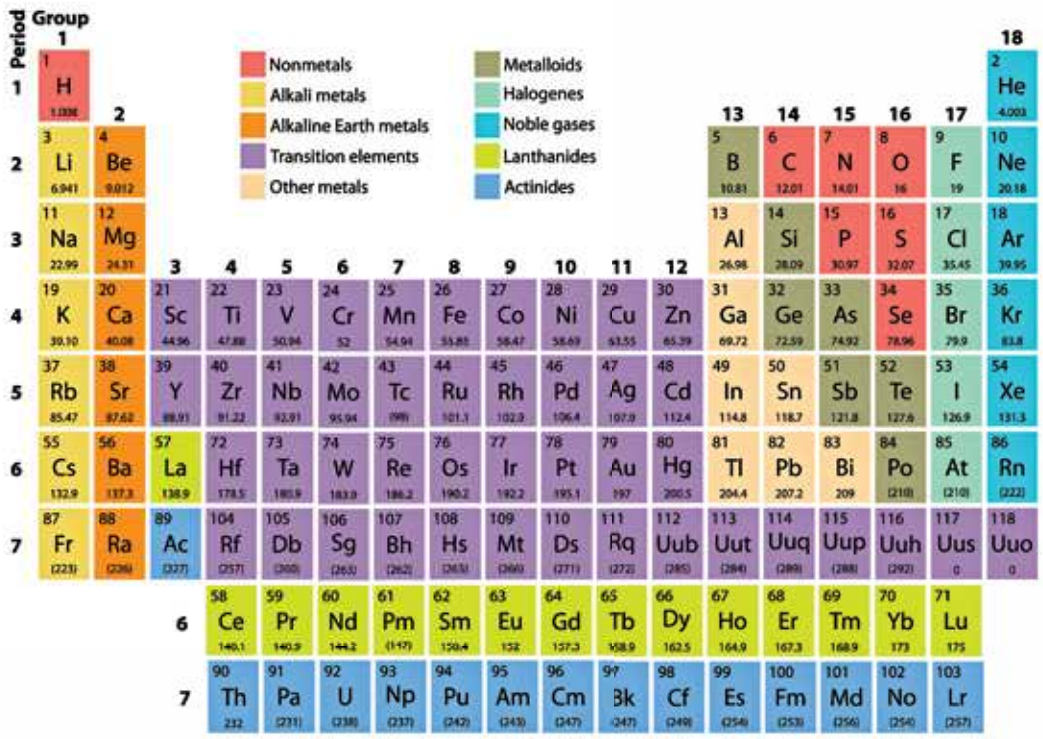
- The video must be between four and five minutes in length.
- The target audience of Science TV is between 8 and 14 years old.
- At least two people must be shown on camera.
- The video must be in the form of a chemistry segment that explains one of the following:
  (a) What is the difference between a physical change and a chemical change?
  (b) What are elements, compounds and mixtures?
  (c) How would we separate a mixture of iron filings, sand, copper sulfate and chalk dust?
- At least one experiment must be shown being performed in the segment — the experiment must be relevant to the segment and safe to perform (i.e. no explosions and no dangerous fumes produced).

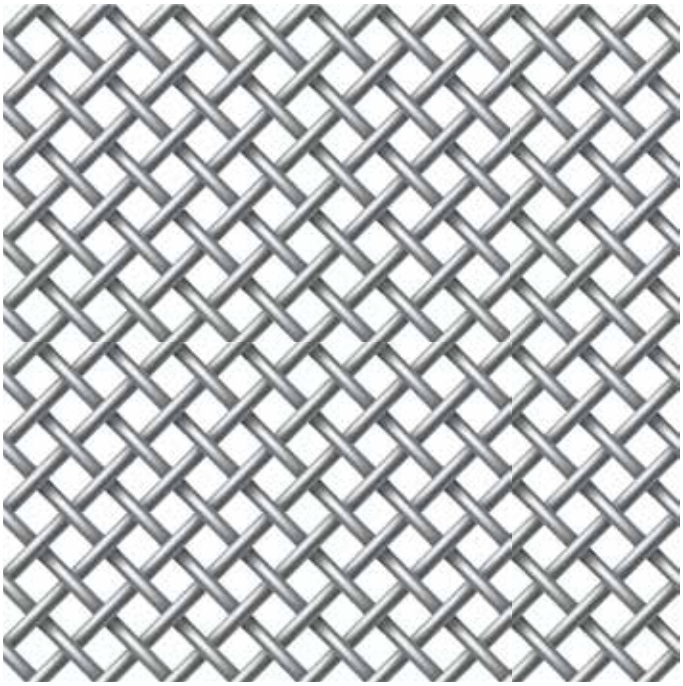
The segment should be engaging and informative. It should have an introduction (either a scenario played out or a discussion between the presenters), an experiment to either test or demonstrate an idea, an explanation of the main concepts involved and a resolution that ties back into the original scenario or discussion. Remember: the main idea is to show that science is FUN!

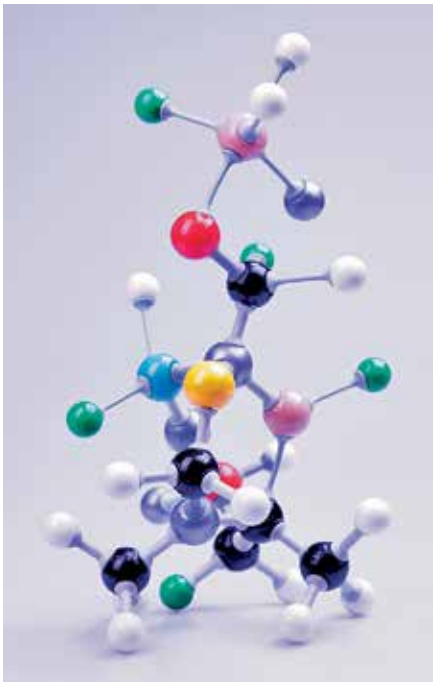


Process

Research. Make notes of ideas that you can use in your segment, including interesting facts, good experiments and ways in which you could make your topic easier to understand — remember that the audience of Science TV is between 8 and 14 years old.







SUGGESTED SOFTWARE

- ProjectsPLUS
- Word processing software (e.g. Word)
- Movie Maker (PC) or iMovie (Mac) or other video editing software
- Internet access

9.12 Review

9.12.1 Study checklist

Atoms

- **describe** the structure of an atom 9.3
- **compare** the models of the atom put forward by Democritus, Dalton, Thomson, Rutherford and Bohr 9.2
- **recall** the three main particles that make up an atom and where they are found in the atom 9.3
- **explain** what makes atoms different from each other 9.3, 9.4
- **recall** how an atom differs from a molecule 9.6–9.8

Elements

- **contrast** the characteristics of metals, non-metals and metalloids 9.5
- **classify** common elements as metals, non-metals or metalloids 9.5
- **identify** the chemical symbols for common elements 9.4–9.6
- **distinguish** between natural and synthetic elements 9.3–9.5
- **define** the term 'allotrope' 9.10
- **describe** what is meant by the term 'alloy' 9.9
- **recall t**he metals that make up common alloys such as brass, steel and bronze 9.9
- **describe** how carbon is recycled in nature 9.10

Compounds

- **describe** how elements are different from compounds 9.6
- **describe** how compounds differ from mixtures 9.6
- **recall** examples of compounds that have different physical properties from the elements they are made from 9.6, 9.7
- **identify** common compounds 9.6–9.8
- **explain** how compounds may be broken up into their component elements 9.6
- **explain** how molecules of elements differ from those of compounds 9.7
- **recall** what a polymer is and give two examples each of natural and synthetic polymers 9.8

Individual pathways

ACTIVITY 9.1
Revising the structure of matter
doc-10561

ACTIVITY 9.2
Investigating the structure of matter
doc-10562

ACTIVITY 9.3
Investigating the structure of matter further
doc-10563

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FOCUS ACTIVITY

online only

Imagine you are a scientist who is investigating what is produced when various chemicals are mixed together.–In one reaction a hard, bright green solid is produced. You do not know what it is. Suggest some tests you could do to help you decide whether it is an element or a compound.

Access more details about focus activities for this topic in the Resources tab (doc-10560).

assessON

9.12 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. Copy and complete the following table, which **describes** the structure of atoms.

Part of atom	Location	Size and weight (relative)	Electric charge
		Large	Positive
Neutron			
	Outside the nucleus		

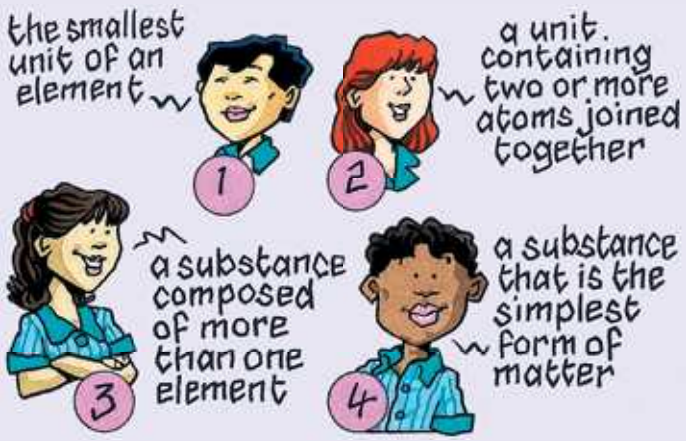
2. Complete the following table to **summarise** what you know about metals and non-metals.

Property	Metals	Non-metals
Conduct electricity well		
Conduct heat well		
Surface features		
State at room temperature		
Malleable		
Ductile		
Brittle		

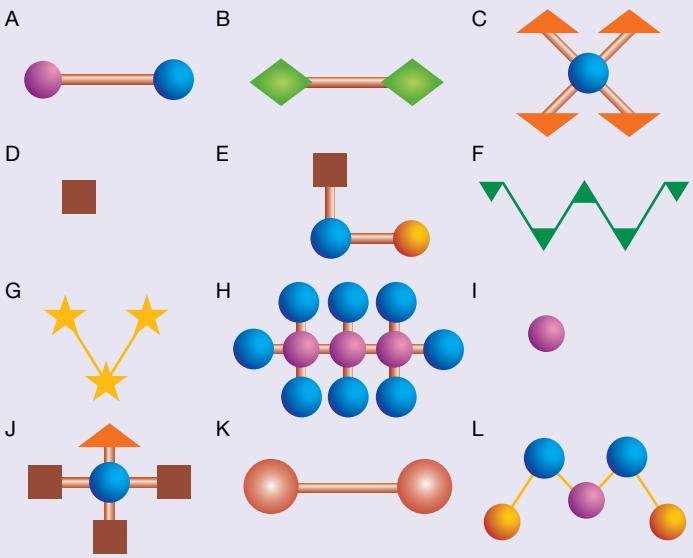
3. **Identify** which of the following are (a) metals and (b) non-metals.
   chlorine gas, sodium, silver, lead, sulfur, oxygen, silicon
4. Complete the table below to identify whether the substances listed are elements, compounds or mixtures. **Explain** your decisions.

Substance	Element, compound or mixture?	Why do you think so?
Gold		
Diamond		
Carbon dioxide		
Air		
Sea water		
Pure water		
Iron		
Ammonia		
Table salt (NaCl)		

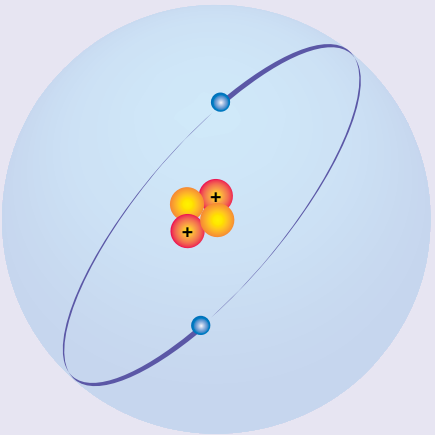
5. Most of the substances around you are compounds and mixtures.
   (a) **Describe** the differences between a mixture of hydrogen and oxygen and a compound of hydrogen and oxygen.
   (b) In your own words, **explain** the difference between a compound and a mixture.
   (c) **Deduce** which elements you would be most likely to find in their pure form around the home.
6. **Describe** what diamonds, the 'lead' in pencils and coal have in common.
7. **Identify** which of the 'structures of matter' is represented by each of the cartoons below.



8. Each of the diagrams at right represents one of the 'bits of matter' that make up substances.
   Identify which of the diagrams represents:
   (a) an atom of an element
   (b) a molecule of an element
   (c) a molecule of a compound.
9. The famous crime writer Agatha Christie mentioned the metalloid arsenic frequently in her novels. **Propose** why it was important in her stories.
10. **Identify** which of the following substances are elements, compounds and mixtures.
    gold, air, carbon dioxide gas, sea water, oxygen gas, sodium chloride, graphite, orange juice, aluminium metal, ice-cream, pure water



11. Are all allotropes molecules? **Explain.**
12. **Describe** the plum pudding model of the atom.
13. What is an alloy? **Identify** the metals that make up the following alloys.
    (a) Bronze
    (b) Solder
    (c) Stainless steel
    (d) Brass
14. If a neutral atom has 12 protons, how many electrons does it have?
15. What takes up most of the volume in an atom?
16. **Identify** the one feature that every single atom of the element sodium has in common.
17. What is the atomic number of each of the following elements?
    (a) Hydrogen
    (b) Carbon
    (c) Uranium
18. How many protons does each of the elements listed in question 17 have in their nuclei?
19. How many electrons does each of the elements listed in question 17 have in their nuclei?
20. Make a copy of the diagram of the atom at right and label an electron and the nucleus. Answer the following questions.
    (a) How many protons does this atom have?
    (b) How many neutrons does this atom have?
    (c) How many electrons does this atom have?
    (d) What is the atomic number of this atom?
    (e) **Describe** one use of the element that is made up of these atoms.



21. What event must take place in order to separate a compound into separate elements?
22. How are the molecules in polymers different from the molecules of other compounds?
23. Respiration is a chemical reaction in which carbon dioxide is produced.
    (a) Where in your body does respiration take place?
    (b) What is released during respiration apart from carbon dioxide?
    (c) Suggest how the carbon atoms in carbon dioxide enter your body.
24. Why doesn't water appear in the periodic table?

Test yourself

1. A compound is a substance that is
   (A) made up of one type of atom.
   (B) made up of different atoms mixed together.
   (C) always a solid.
   (D) able to be broken down into the elements it is composed of. **(1 mark)**
2. The central section of an atom is called the
   (A) nucleus.
   (B) electron.
   (C) middle.
   (D) neutron. **(1 mark)**
3. The chemical symbol for silver is
   (A) Si.
   (B) S.
   (C) Ag.
   (D) Sr. **(1 mark)**
4. The 'plum pudding' model of the atom was first proposed by
   (A) Democritus.
   (B) Ernest Rutherford.
   (C) Niels Bohr.
   (D) JJ Thomson. **(1 mark)**

5. **Imagine** you are a scientist in charge of developing new materials. The Australian Space Agency has approached you because they need a new substance to coat the outside of the space shuttles they are designing. The substance must be:
   - able to withstand the heat of the shuttle re-entering the Earth's atmosphere
   - flexible enough to bend when the wings of the shuttle bend
   - strong enough to stand the vibration of take-off, landing and other movement
   - light enough to be part of a flying spacecraft
   - resistant to chemical attack
   - able to reflect the solar radiation in space.

   Your task is to design the coating for the space shuttle. Include:
   (a) whether it will be solid, or an innovative liquid or gas coating. It could be a combination of these in layers or as a mixture!
   (b) what atoms, elements or compounds it will be made of
   (c) how the coating of substances will work to meet the criteria from the Australian Space Agency. This will include the properties of your substances and how they are put together.
   (d) a drawing of your coating indicating its special features and how it works. **(6 marks)**

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Complete this digital doc: Worksheet 9.7: Bits of matter puzzles (doc-12426)

Complete this digital doc: Worksheet 9.8: Bits of matter summary (doc-12427)

TOPIC 10
The changing Earth

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.

10.1.1 Why learn this?

The Earth's surface is constantly changing. While volcanoes and earthquakes can alter a landscape in a matter of days, most of the changes to the Earth's surface happen very slowly. Rocks on and below the surface of the Earth are constantly being changed by natural processes that act over millions of years. As a result, rocks also provide a valuable record of past events.

LEARNING SEQUENCE

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This aquatic reptile died over 300 million years ago. Fossils and the rocks in which they are found provide a valuable record of the past.



Thinking about the changing Earth

The Earth is constantly changing. Some of the changes take millions of years — others take place within seconds.

1. Take a look at each of these images and write down what each tells you about the Earth and the way that the Earth is changing.

(a)



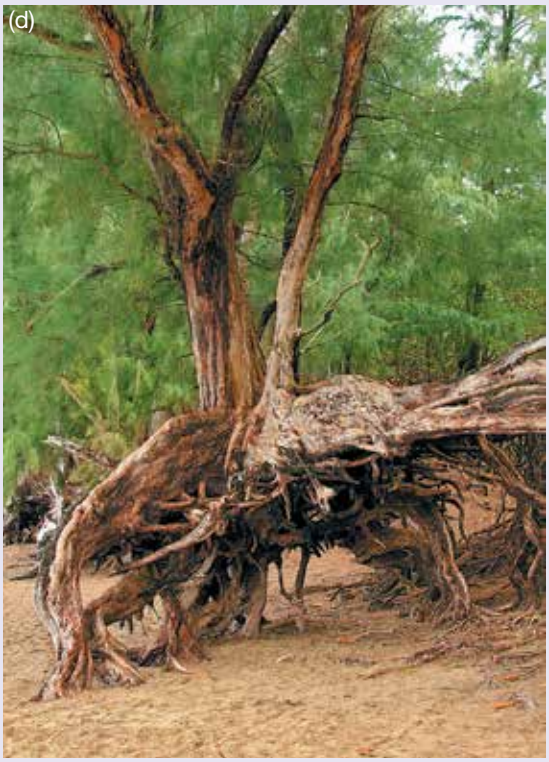
(b)



(c)



(d)



(e)



2. Which one or more of the changes depicted in the photos above are caused or made worse by human activities?
3. How are rocks formed?
4. The terms ‘igneous’, ‘sedimentary’ and ‘metamorphic’ describe different types of rocks. Just from looking at the words, suggest how each type of rock is formed.
5. How many names of rocks do you know? List them and then, if you can, classify them as igneous, sedimentary or metamorphic.

Useful rocks

Humans have long used rocks and the minerals that we can extract from them for a variety of purposes. Consider the rocks in the following photos.

(a)



(b)



(c)



(d)



(e)



6. Match each of the rocks above with its name from this list.
   flint, chalk, marble, pumice, slate
7. Which of the rocks above would you use for:
   (a) benchtops
   (b) floor tiles
   (c) spearheads and arrowheads
   (d) removing calloused skin
   (e) preventing a gymnast's hands slipping from the bar?

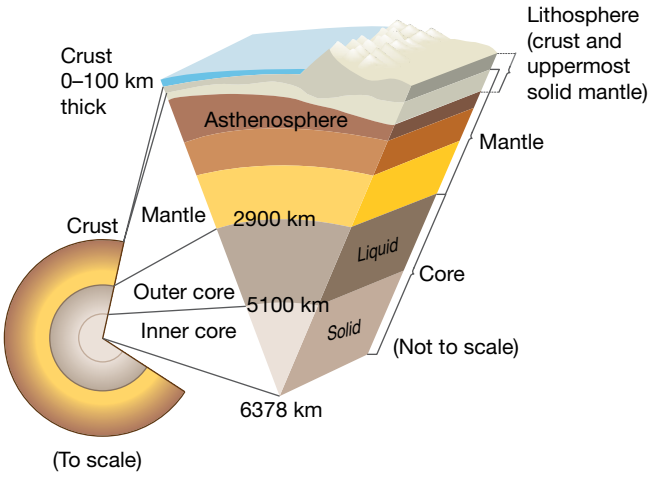
10.2 Solid rock

10.2.1 The lithosphere

The Earth's crust and the topmost sections of the mantle form the Earth's lithosphere (from the Greek words *lithos* meaning 'stone' and *sphaira* meaning 'globe'). It is in the lithosphere that rocks are formed by a variety of different processes such as melting, erosion, weathering, crystallisation and deposition.

Rocks can be divided into three main groups: igneous, sedimentary and metamorphic. In the next few sections, we will look in more detail at how each of these rock groups is formed.

All rocks are formed in the lithosphere — the section of the Earth made up of the crust and the upper mantle.



10.2.2 What are rocks made of?

Rocks are made up of substances that are called **minerals**. The term 'mineral' describes any solid material made up of a consistent combination of chemical substances that occur naturally. These chemical substances can take the form of chemical compounds (which are made up of combined elements) or elements found in their pure form. It is very unusual to find pure elements in nature but gold and diamond (which is made up of carbon that has been subjected to high pressure and heat) are two examples. These types of minerals are referred to as **native elements**.

Iron oxide (left) and magnetite (right) are both minerals made of iron and oxygen but in different proportions.



Most of the minerals that make up the Earth's crust are compounds of oxygen and silicon; these are called silicates. They differ in appearance and in their chemical and physical properties due to variations in what metals they are combined with and the proportion of each element present in the mineral. Two minerals may be made up of the same elements but differ in the proportions. For example, iron oxide (Fe_2O_3) is a reddish brown substance that gives rust its colour, whereas Fe_3O_4 forms magnetite, a dull grey stone.

It can also happen that one mineral can come in a number of different colours. Quartz is made of silicon dioxide (SiO_2) and, in its purest form (rock crystal), is a clear white stone. However, small impurities in the compound as well as differences in the size of the quartz crystals can cause quartz of every colour of the rainbow to exist. Most of the so-called semiprecious stones, including amethyst, citrine and onyx, are varieties of quartz.

Generally, colour alone is not a good indicator of which mineral is present in a sample of rock. After all, a citrine, a topaz and a champagne diamond are all clear yellow stones but they differ completely in chemical composition.

Yep – it's all quartz!

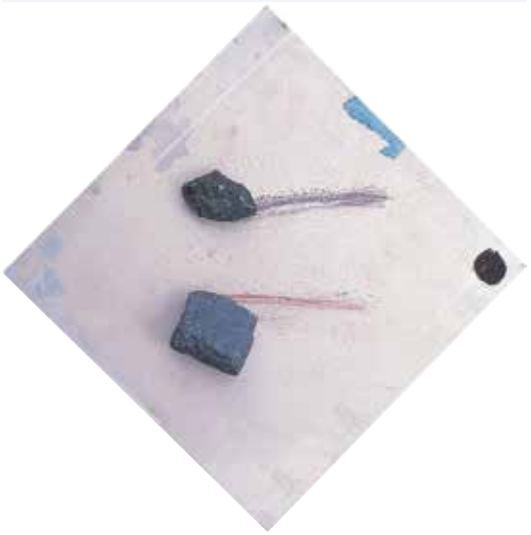


10.2.3 What mineral is that?

Geologists consider a number of different properties in order to identify a specific mineral in a rock sample:

- A mineral's **lustre** describes how it reflects light from its cut surface. The lustre of a mineral may be described as dull, metallic, pearlescent, glassy, brilliant, waxy or silky.
- The **transparency** of the mineral describes how well light travels through it. Opaque minerals (such as iron oxide) do not let light through at all; transparent minerals (such as diamond and pure quartz) allow light to pass easily through them; while other minerals (such as calcite) are translucent, allowing only some light through a sample.
- A mineral's **streak** is the colour and texture of the mark that the mineral leaves behind when it is scratched across a hard white surface. Not all minerals leave a streak.
- The **fracture** of a mineral describes the appearance of the break when a sample of the mineral is snapped. The fracture of a stone can be described using terms such as brittle, conchoidal, plastic or crystalline.
- The mineral's **hardness** is a measure of how easily the surface of the mineral is scratched or dented.

Many minerals leave a streak when rubbed against the rough surface of an unglazed white tile. Hematite has a red-brown streak. The streak left by a mineral and the actual colour of a mineral are not always the same. Not all minerals leave a streak.

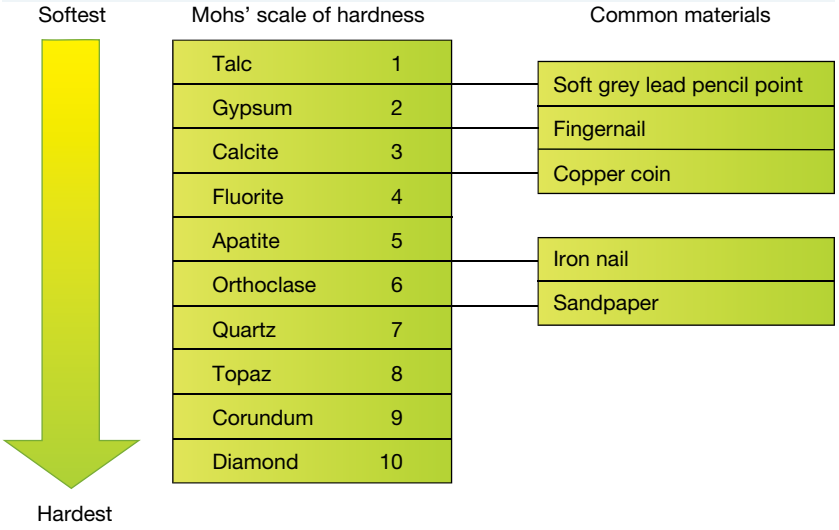


10.2.4 Mohs' scale

Geologists use a system called the **Mohs' hardness scale** to determine hardness. This scale was developed by the geologist Friedrich Mohs; it consists of a comparative list of ten minerals arranged in order from softest (hardness value of 1) up to the hardest (10). A harder mineral scratches a softer mineral. Typical minerals for each of the ten hardness values are shown at right. The hardness of a particular mineral can be found by comparing it with minerals on the Mohs' scale. For example, if the mineral sample can be scratched by a piece of quartz but not by orthoclase, its hardness lies between 6 and 7.

Ideally, you would keep a sample of each of the ten reference minerals handy, but it is possible to use common materials to find a mineral's hardness. Some of these items and their typical hardness values are also shown in the diagram at right.

A scale for testing the hardness of minerals



INVESTIGATION 10.1

Which mineral is it?

AIM: To examine properties of minerals

You will need:

mineral kit
common materials to substitute for unavailable Mohs' scale minerals
magnifying glass
white ceramic tile

- Construct a table like the one shown below and use it to record your observations as you work through the following steps for each mineral.
- Describe the colour and lustre of the mineral.
- Use the magnifying glass to look closely at the mineral and describe the shape and size of its crystals.
- Scrape the mineral across the unglazed side of a white ceramic tile. Record the colour of the streak.
- Use the Mohs' scale minerals or the common materials to estimate the hardness of the mineral by trying to scratch it. An approximate range, such as 5—6, is sufficiently accurate.

Discussion

1. Other than those already described, what additional properties of minerals could be used to identify them?
2. If two unlabelled mineral samples have the same colour and lustre, can you be sure that they are the same mineral? Explain how you would find out.

Properties of some minerals

Mineral	Colour	Lustre	Crystal shape and size	Streak	Hardness

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. **Describe** what the lithosphere is and where it can be found.
2. **Define** the term 'mineral'. **Recall** at least two examples of minerals.
3. **Recall** two examples of native elements.
4. **Identify** which minerals are present in granite.
5. **Recall** at least three properties that you could observe to help you identify an unknown mineral.
6. **Identify** the approximate Mohs' scale hardness (to the nearest whole number) of a mineral that can be scratched by sandpaper but not by an iron nail.
7. **Explain** how minerals that contain the same elements can have different physical and chemical properties.

Think

8. **Distinguish** between a rock and a mineral.
9. **Explain** what the size of the crystals in a rock tells you about the way the rock was formed.
10. You have a sample of each of two minerals but no other equipment to test them for hardness. How could you tell which mineral was harder? **Explain** your answer.
11. A mineral can be scratched by a copper coin but not by a fingernail. You know that the mineral is quartz, fluorite or calcite. Which mineral is it? **Justify** your answer.
12. Is table salt a mineral? Think carefully about your answer and suggest reasons for and against classifying it as a mineral.

Investigate

13. Find out what the different fracture types, such as conchoidal, plastic, brittle and crystalline, mean. Find examples of stones that show these fractures.

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Complete this digital doc: Worksheet 10.1: Identifying and classifying minerals (doc-12428)

10.3 Fiery rocks

10.3.1 Igneous rocks

Think about the word 'igneous' for a moment. Does this word remind you of any other words? How about 'ignite' or 'ignition'? In fact, all of these words have a common origin and they come from the Latin word *ignis* meaning 'fire'. So, we can think of igneous rocks as coming from a hot, fiery place.

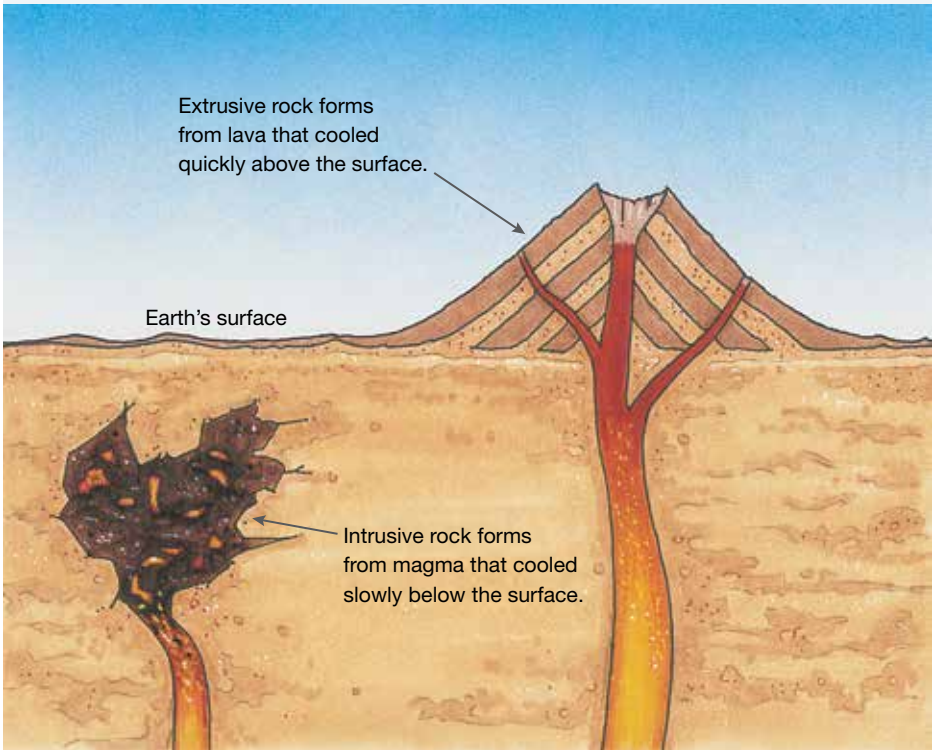
Igneous rocks are formed from molten rock from the upper sections of the mantle. The temperature in this part of the mantle can reach as high as 1400 °C. The molten rock from the mantle is called **magma**. The magma is pushed upwards into the crust by pressure in the mantle. In some places, the crust is very weak or has been ruptured so the magma can break through and flow onto the Earth's surface. Magma that flows onto the Earth's surface is called **lava**. Volcanoes are formed where the crust is weak, allowing magma to break through.

Igneous rocks can be formed from either magma or lava. Those that have formed from magma that cooled below the surface are called **intrusive rocks** or **plutonic rocks**. They cool slowly and become visible only when the rocks and soil above them wear away. Large bodies of intrusive rock are called **batholiths**. These can stretch over distances of up to 1000 kilometres.

Igneous rocks that are formed from lava cooling above the surface are called **extrusive rocks**. They generally cool very quickly. Igneous rocks that form from lava spilling from underwater volcanoes are also classified as extrusive rocks.

The appearance of an igneous rock depends on what substances were in the molten material from which it was made and how quickly the molten rock cooled.

Igneous rocks can form below or above the Earth's surface.



10.3.2 Crystal clear

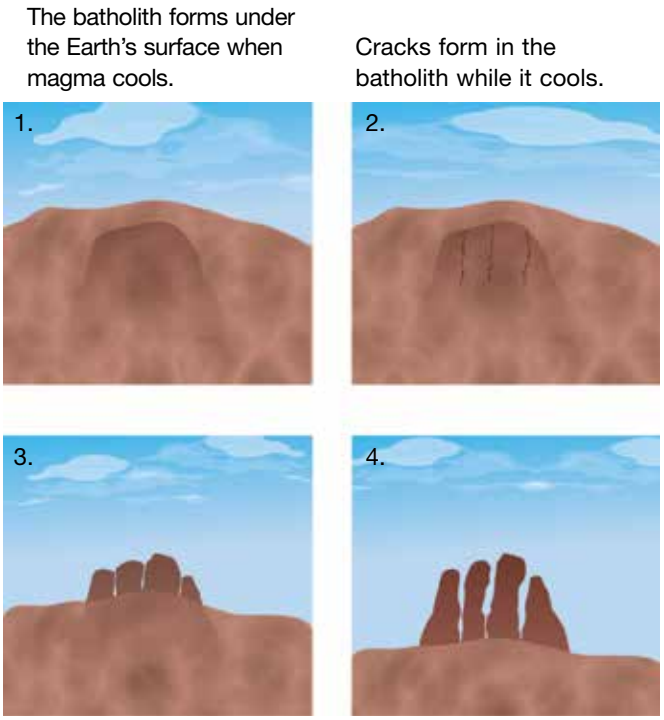
Crystals are formed when the atoms of a liquid arrange themselves into regular three-dimensional geometric patterns when the liquid becomes a solid. The longer the liquid takes to solidify, the more time the atoms have to arrange themselves and form larger crystals.

The shape of the crystals depends upon how the atoms pack themselves, which, in turn, depends upon what types of atoms are present. Geologists can usually identify a mineral based on its crystal shape.

When lava or magma cools, the liquid rock crystallises to form igneous rock. The size of the crystals in an igneous rock depends on how quickly it cooled. Intrusive rocks have larger crystals than extrusive rocks because the crystals have had more time to grow. When lava emerges from a volcano, contact with the cool air or cold water makes it cool very quickly, not giving large crystals time to grow.

Pressure also affects the growth of crystals; the higher the pressure exerted on the rock as it cools, the larger the crystals that are formed. This is another reason why intrusive rocks usually have larger crystals; the pressure acting on them as they form is much larger than is exerted on rocks that form on the surface of the Earth.

If a batholith is exposed to the environment, it will start to wear away along the cracks. Over time, the batholith may break down completely. The breakdown of rocks is called weathering.



The softer rocks and soil around the batholith may wear away.

INVESTIGATION 10.2

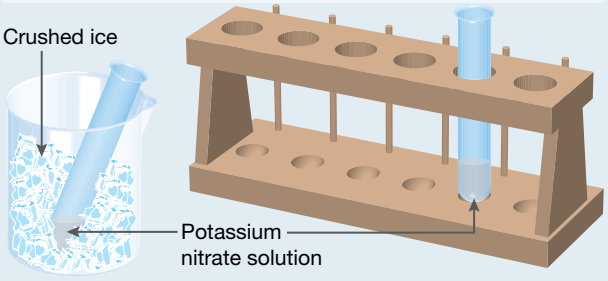
Does fast cooling make a difference?

AIM: To produce large and small crystals

You will need:

freshly made saturated solution of potassium nitrate
potassium nitrate
spatula
250 mL beaker
3 test tubes and test-tube rack
test-tube holder
Bunsen burner, heatproof mat and matches
crushed ice
safety glasses
hand lens

Cool one solution quickly and the other one slowly.



CAUTION: Safety glasses must be worn during this experiment.

- Half-fill a beaker with crushed ice.
- Quarter-fill a clean test tube with saturated potassium nitrate solution. Add a spatula of potassium nitrate to the solution.
- Gently heat the solution over a Bunsen burner flame until the added potassium nitrate has dissolved or until the solution starts to boil.
- Pour half the warm solution into each of two clean test tubes.
- Place one test tube in the beaker of crushed ice and the other test tube in the rack to cool.
- When crystals have formed in each test tube, examine them with a hand lens.

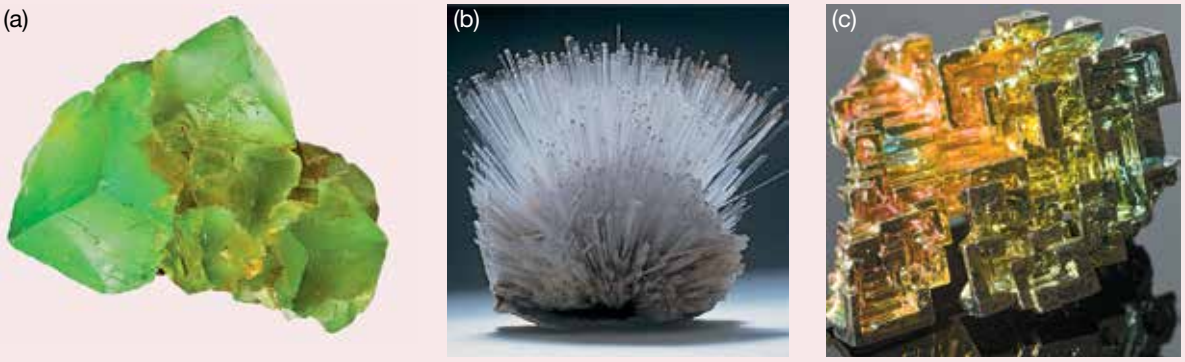
Discussion

1. Draw a labelled diagram of some crystals in each test tube, concentrating on their shape and size.
2. Which test tube contained the largest crystals — the one that cooled quickly or the one that cooled slowly?
3. Which type of igneous rock would you expect to have larger crystals, those that cool slowly beneath the surface or those that cool quickly above the surface or under water?
4. Why do safety glasses need to be worn in this experiment?

HOW ABOUT THAT!

Some of the largest single crystals are found in the Merkers potash mine in Germany where cube-shaped halite crystals can measure over a metre across.

Crystals can come in a variety of shapes and sizes: (a) fluorite, (b) mesolite, (c) bismuth.



10.3.3 Common igneous rocks

Frothy rocks

Some violent volcanic eruptions shoot out lava filled with gases. The lava cools quickly, while it is still in the **air**, and traps the gases inside. Rocks that form this way are full of holes. Two examples of these rocks are **pumice** and **scoria**.

Pumice

Pumice is a pale-coloured rock. It is very light because it is full of holes. It floats on water and sometimes washes up on beaches. Powdered pumice is used in some abrasive cleaning products.

Scoria

Scoria is heavier than pumice and has more iron so it is darker than pumice. It is usually found closer to the volcano's crater than pumice. Scoria is a red-brown or grey rock that can be used in garden paths or around drainage pipes.





10.3.4 Basalt

Basalt is an extrusive rock that can take on many appearances. One big difference between samples of basalt is the size of the crystals that make up the rock.

Basalt with bubbles

When viewed under a microscope, it is apparent that the crystals in this basalt are large. This is because they formed from lava on the ground. The crystals had time to grow before the rock became solid. Notice the holes. The lava was filled with gases when it began to cool. The gases have since escaped.





Pillow basalt

This rock formation came from a volcano that was once under water. The rocks formed from underwater volcanoes are smooth and round. The crystals in this basalt are so small that they are difficult to see.

10.3.5 More common igneous rocks

Obsidian

Obsidian is a smooth, black rock that looks like glass. It is formed when lava cools almost instantly. This rock is different from basalt because it cooled so quickly that no crystals formed. Sometimes very fine air bubbles are trapped in the rock, which give it a coloured sheen.



Granite

Granite is a common intrusive rock. The crystals in granite form over long periods of time and grow large enough to make them easy to see with the naked eye. Granite is very hard and can be used for building. Headstones and other monuments can be made from granite that has been polished to give it a glossy finish.

The crystals found in granite are a mixture of white, pink, grey, black and clear minerals. These are quartz (clear to grey), feldspar (white and pink) and mica (black). Feldspar is made of aluminium silicate, and black mica is aluminium silicate combined with potassium, magnesium and iron.



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.

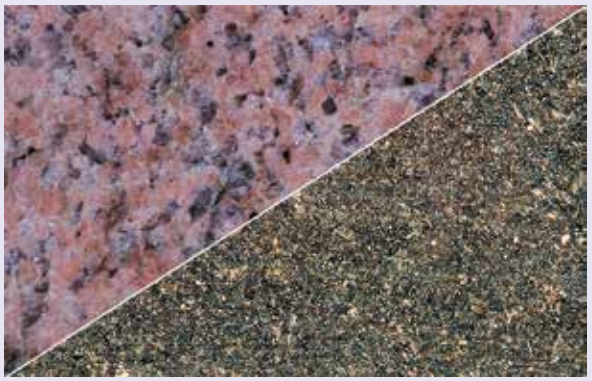
Remember

1. **Describe** two ways in which you can **distinguish** between intrusive and extrusive rocks.
2. **Recall** how a batholith is formed.
3. **Summarise** the differences between granite and basalt.
4. **Recall** why the crystals in pillow basalt are smaller than the crystals in basalt that formed on the ground.
5. **Identify** the factors that affect crystal growth in cooling rocks.
6. Scoria and pumice are formed in a similar way. **Explain** why their colours are different.
7. **Recall** what type of extrusive rock could easily be mistaken for glass.
8. **Describe** one way in which intrusive rocks can become visible on the Earth's surface.
9. **Explain** why pumice is so light.

Think

10. **Explain** how you would decide whether an igneous rock came from a volcano.
11. Rhyolite is an extrusive rock that contains the same minerals as granite. In what way would you expect it to be different from granite?

12. In which of the two rocks at right did the lava cool faster? **Explain** your answer.
13. **Describe** what the presence of 'bubbles' in rocks tells us about lava.
14. **Identify** which of the following are true.
    (a) All intrusive rocks form batholiths.
    (b) Rocks are made up of substances called minerals.
    (c) All igneous rocks are extrusive rocks.
    (d) Intrusive rocks are more likely to have larger crystals than extrusive rocks.
    (e) Batholiths come from volcanoes.



Investigate

15. Locate a building, statue or memorial in your area made from granite. **Describe** the granite in the building or structure and **explain** why granite's features make it so useful.
16. Some people believe that different crystals have special properties to help your mood and health.
    (a) **Investigate** where this idea originated.
    (b) Briefly **discuss in a small group** how you would test the existence of these properties experimentally.
17. Use the **Who am I?** weblink in the Resources tab to play the Rock Game and identify rocks from a series of clues.

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Complete this digital doc: Worksheet 10.2: Igneous rocks (doc-12429)

Explore more with this weblink: Who am I?

10.4 Wearing away

10.4.1 Weathering

Volcanoes continue to erupt, leaving igneous rocks on and under the Earth's surface, yet the surface of the Earth's crust isn't a huge mass of solid rock. The actions of wind, water and ice constantly break down rocks on the Earth's surface.

The process of breaking down rocks is called **weathering**. Weathering is a slow process, but the rate at which it happens depends on the type of rock and the natural action involved. In a climate as severe as Australia's, we can see many different examples of weathering.

The action of the sea breaks off pieces of coastal rock, often leaving spectacular features such as the Twelve Apostles at Port Campbell National Park, Victoria.

The wind wears rock away, especially in dry conditions when it blasts the rock with sand and soil it has picked up.

Acid rain can form if there is a lot of pollution in the air. It can react with chemicals in rocks, making them crack and crumble more easily.

The Twelve Apostles, on the coast of southern Victoria



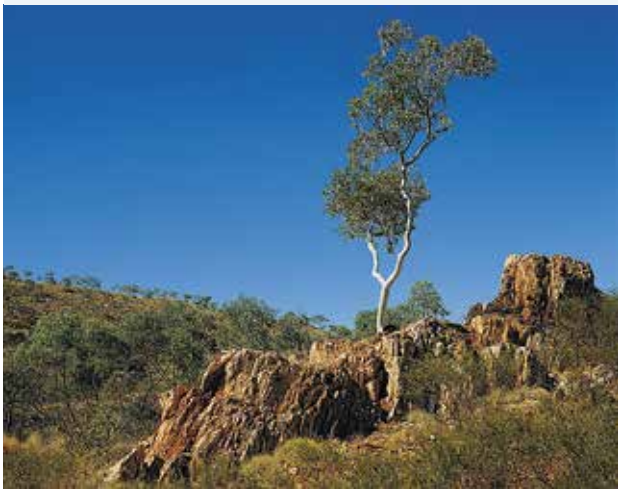
Water on the ground can react with certain chemicals in rocks, soil and decaying plants, producing acids and bases that speed up the weathering of rocks.

Weathering doesn't change only rocks. It changes buildings, roads and cars — even your own skin weathers as you get older!

Wave Rock, Western Australia, a spectacular example of weathering by the wind and chemicals



Tree roots widen the cracks in rocks.



INVESTIGATION 10.3

Chemical weathering

AIM: To demonstrate rock weathering

You will need:

piece of limestone
distilled water
dilute hydrochloric acid
2 dropping pipettes

- Put a drop of distilled water on the piece of limestone.
- Put a drop of dilute hydrochloric acid on a different part of the piece of limestone.

Discussion

1. Does the distilled water have any observable effect on the limestone?
2. What is the effect of the dilute acid on the limestone?

10.4.2 Carried away

Weathered rock is usually moved from one place to another by the wind, running water, the sea or glaciers. This process is called **erosion**. The weathered rock moved by erosion is deposited and settles on the land, riverbeds and floors of lakes, seas and oceans to form **sediments**. Deposits of dead plants and animal remains are also called sediments.

Soil is formed by weathering, erosion and **deposition** of rock. Soil also contains **humus** — decaying plant and animal material that plants can grow in.

A fast-moving river is likely to carry sand, gravel and smaller particles with it. As it slows down on its path to the sea, it loses energy, and particles are deposited, forming sediments. The larger particles, such as gravel and sand, settle first. By the time the river reaches the sea, it is usually travelling so slowly that the very fine mud particles begin to settle.



1. Fast-flowing water can move sand, soil and even big rocks over long distances. All creeks and rivers flow to the sea or to inland lakes, but, by the time they reach the seas or lakes, the water flows much more slowly.
2. As the water slows down, the bigger rocks are deposited.
3. By the end of the river's journey, all but very fine sediments have been deposited.
4. Coastlines can change quite quickly as a result of weathering, erosion and the deposition of sediments.
5. Ocean waves wear away the rocks that make up cliff faces. The waves pound rocks, smashing them into smaller and smaller pieces.
6. Sand is picked up by currents in the waves along one beach and deposited on other beaches. Strong winds have enough energy to pick up sand and carry it inland.

HOW ABOUT THAT!

Cracking up

Some objects, like glass, crack if their temperature changes quickly. Rocks can do the same. The cracking occurs because the outer part of the rock cools more quickly than the inside of the rock after a hot day. Cracking can also occur when it rains on a hot day. The cracks gradually get larger, until large flakes begin to fall off. Granite often weathers this way.

Trees can begin to grow within cracks in rocks. As the trees grow, the cracks are forced apart, eventually splitting the rocks. This speeds up weathering.



INVESTIGATION 10.4

Sediments and water

AIM: To demonstrate sedimentation

You will need:

mixture of garden soil, gravel, sand and clay
large jar with lid
watch or clock

- Before commencing this experiment, form your own hypothesis about the order in which the different types of particles in the mixture will settle. Give reasons for your hypothesis.
- Place enough of a mixture of garden soil, gravel, sand and clay in a large jar to quarter-fill it.
- Add enough water to three-quarters fill the jar and place the lid on firmly. Shake the jar vigorously.
- Put the jar down and watch carefully as particles begin to settle.
- Note the time taken for each layer of sediment to settle completely.
- Leave the jar for a day or two. Then compare your observations of the jar with your diagram.

Discussion

1. Which type of sediment settled after you first shook the jar?
2. Where were the other particles of sediment while the first layers were settling?
3. Draw a labelled diagram showing clearly any layers that formed. Identify the layers if you can.
4. Which sediments settled after a day or two?
5. Why did the last sediments take so long to settle?
6. Was your hypothesis supported by your observations?
7. What is the relationship between the size of sediment particles and the time taken to settle?

10.4 Exercise: Remember and think

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Remember

1. **Define** the term ‘weathering’.
2. **Recall** five causes of weathering.
3. **Define** erosion, and **describe** how it differs from weathering.
4. **Distinguish** between a soil and a sediment.
5. As a flooded river slows down, **identify** which particles are likely to settle first: gravel, sand or fine clay.

Think

6. The Sphinx and the Great Pyramids of Egypt have stood for thousands of years, yet weathering has affected them more during the past 50 years than in the previous years since they were built. **Describe** the most likely cause of increased weathering.
7. Acid rain is a serious problem in industrial areas where there is a lot of air pollution. However, rain reaching the ground after falling through clean air is also slightly acidic. **Explain** how this could be.
8. **Identify** which feature of Wave Rock is the result of:
   (a) weathering by wind
   (b) weathering by chemicals.
9. **Describe** some evidence of the weathering of:
   (a) buildings (b) cars (c) roads.
10. **Compare** the sediment found at the bottom of a still lake with the sediment on the banks of a mountain stream.
11. In alpine regions, rocks can be shattered by frozen water. **Explain** how this can happen.
12. What type of sediment would you expect to find on the bed of the Yarra River in Melbourne, the Derwent River in Hobart or the Swan River in Perth?
13. The Twelve Apostles were originally named because 12 'stacks' were close together along the western Victorian coast. Some of the stacks have since collapsed into the sea.
    (a) What is probably the main cause of the weathering of these stacks? **Explain**.
    (b) Which part of each stack is likely to weather most quickly? **Justify** your answer.
    (c) Has this coastal feature been caused by weathering, erosion or both? **Explain** your answer.
14. Why are larger sediments deposited before finer ones in river systems?
15. How much weathering and erosion would take place on the moon? How long would you expect a footprint to remain on its surface? **Justify** your answers.

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Complete this digital doc: Worksheet 10.3: Weathering and erosion (doc-12430)

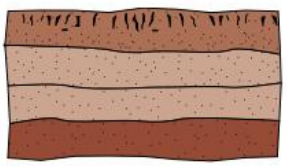
10.5 It's sedimentary, Watson!

10.5.1 Sedimentary rocks

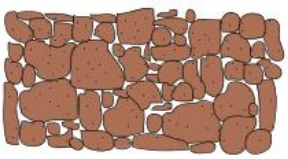
Rocks that are formed from particles of sediments are called **sedimentary rocks**. These sediments may come from weathered and eroded rock or even be the fragmented remains of once-living creatures. The grains of sediment are compressed under great pressure or cemented together by dissolved compounds over a long time to form a solid rock.

This process is shown in the diagrams at right.

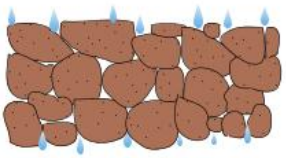
Many sedimentary rocks form in this way.



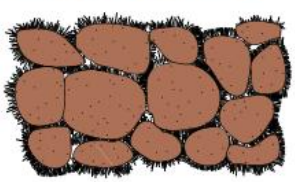
Sediments are laid down by ice, wind or water, in horizontal layers called beds.



Within each bed, the sediment grains are squashed together so that they are in close contact.



Water seeps in between the grains, bringing with it many dissolved chemicals.



When the water evaporates, these chemicals are left behind as crystals around the edges of the grains. These crystals cement the grains of sediment together to form rock.

10.5.2 Clastic sedimentary rocks

Sedimentary rocks can be categorised according to the type of material that the sediments are made of. Most sedimentary rocks are made of **clastic** material — pieces of older rocks that have been eroded and deposited. As a result, clastic sedimentary rocks are made from minerals, such as quartz, feldspar and mica, or particles of clay or sand.

Sandstone is formed from grains of sand that have been cemented together over a long time.



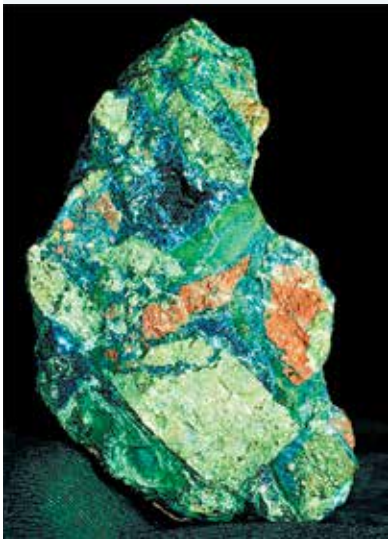
Mudstone and **shale** are both formed from finer grains of sediment deposited by calm water in the form of mud; however, shale has been compressed more and forms thin flakes when broken.



Siltstone has grains slightly larger than those of mudstone or slate.



Conglomerate contains many different sizes of particle from fine grit to rounded pebbles. It is often referred to as 'pudding stone'.



10.5.3 Organic sedimentary rocks

Sedimentary rocks that are made from material that was once part of a living organism are referred to as **organic sedimentary rocks**. Rocks such as **limestone** are formed from calcium carbonate. This compound comes from the hard shells and exoskeletons of ancient sea organisms that were cemented together with silt and compressed by the sediment layers forming above them on the ocean floor.

Coal

Coal is formed from the remains of dead plants that are buried by other sediments. In dense forests, layers of dead trees and other plants build up on the forest floor. If these layers are covered with water before rotting

HOW ABOUT THAT!

The chalk used to write on blackboards is like limestone, but it is not as hard as most limestone. Chalk is formed from very fine grains of calcium carbonate that have separated from sea water and settled to become a white, muddy sediment on the sea floor. The sediment hardens over time to form chalk. This process takes millions of years. The remains of shellfish and other sea animals are also found in the sediment that forms chalk, but most of these remains are microscopic.

The white cliffs of Dover that overlook the English Channel are composed of chalk.



is completed, they can become covered with other sediments. The weight of the sediments above compacts the partially decayed plant material. Over millions of years the compacting increases the temperature of the sediment and squeezes out the water, forming coal.

10.5.4 Rocks in layers

Layers of sedimentary rock are often clearly visible in road cuttings and the faces of cliffs. The limestone in the photograph at right was formed on the ocean floor. Layers of sediments and sedimentary rocks can be pushed upwards by the same forces below the Earth's surface that cause mountains to be formed. Those forces can also bend and tilt the layers.

Using sedimentary rocks

Sandstone and limestone are often used as external walls of buildings. These sedimentary rocks are well suited to carving into blocks of any shape. Shale can be broken up and crushed to make bricks.

Limestone is broken up to produce a chemical called lime. Lime is used to make mortar, cement and plaster, in the treatment of sewage and on gardens to neutralise acid in the soil.

Coal is used as a fuel. It is burned in electric power stations to boil water. The steam is then used to drive the turbines that produce electricity. In some countries, coal is burned in home heaters.

This limestone, rich in corals and shells, is many metres above sea level. How did it get there?



Layers of sedimentary rock can be pushed upwards, bent and tilted by forces beneath the Earth's surface.



INVESTIGATION 10.5

Identifying sedimentary rocks

AIM: To identify a range of sedimentary rocks

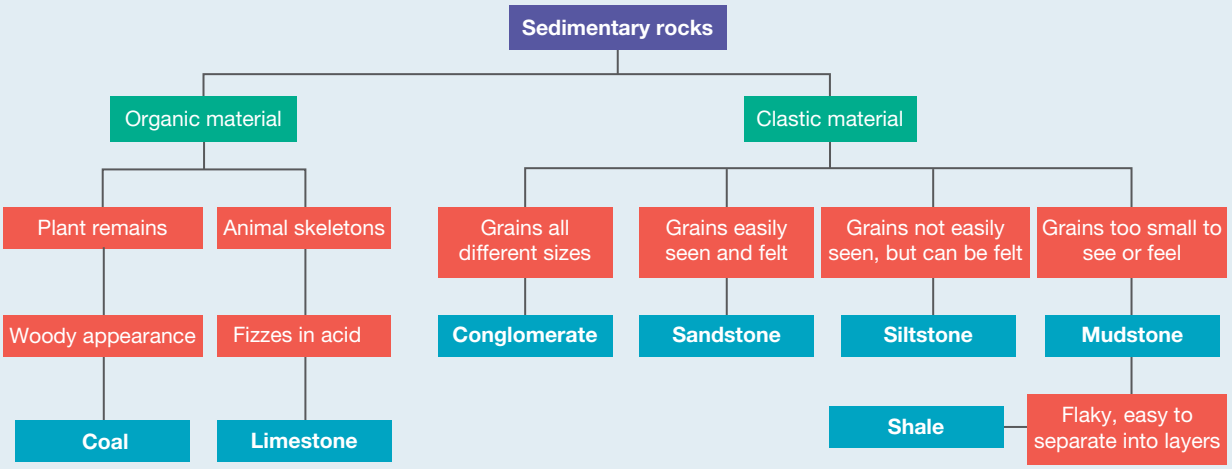
You will need:

several examples of unlabelled sedimentary rocks, including limestone
dropping bottle of dilute hydrochloric acid

- Use the key below to identify the samples of sedimentary rocks that you are provided with.
- To do the acid test, just add one drop of dilute hydrochloric acid onto the sample.

Discuss and explain

1. How many of the unlabelled rocks did you correctly identify?
2. Which of the rock samples were the most difficult to identify?



10.5 Exercise: Remember and think

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Remember

1. **Recall** what all sedimentary rocks are formed from.
2. **Explain**, with the aid of a diagram, how grains of sand can become part of a sedimentary rock.
3. Sedimentary rocks that have formed from the erosion of weathered rock cannot be identified by their colour. **Recall** the feature that allows you to identify them.
4. **Describe** the difference between clastic and organic sedimentary rocks.
5. **Explain** how a rock can be formed from the remains of animals.
6. **Recall** how coal is formed.
7. **Recall** how mudstone is different from shale.

Think

8. **Explain** why sedimentary rocks are found in layers.
9. A road cutting reveals a layer of sandstone beneath a layer of mudstone. Between them is a much thinner layer of conglomerate. **Identify** which layer would have formed:
   (a) from sediments beneath the sea
   (b) while the area was flooded by a swollen, fast-flowing river
   (c) while the land was the floor of a still lake
   (d) most recently.

10. **Explain** why limestone and coal are sometimes referred to as 'biological rocks'.
11. Limestone is mostly formed on the ocean floor. **Account** for the fact that the Nullarbor Plain is riddled with limestone caves.
12. In which type of sedimentary rock would you be most likely to find embedded seashells? **Explain**.

Investigate

13. What do peat, brown coal and black coal have in common? **Investigate** what makes them different from each other.

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Complete this digital doc: Worksheet 10.4: Sedimentary rocks (doc-12431)

10.6 Time trapped in rocks

10.6.1 Layers of clues

Sedimentary rocks form in layers. Each new layer forms on top of the older layers below. Sedimentary rocks are therefore useful for giving scientists clues about the order in which events happened. Sudden events, such as exploding volcanoes, are recorded in the layers. Slow movements beneath the surface can also be seen in the layers.

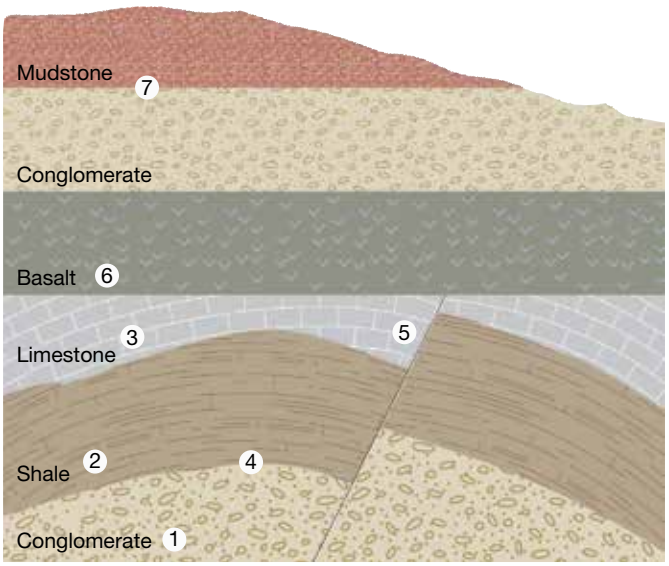
10.6.2 Living in the past

The layers in rocks are useful for finding out about the order of events in a particular area. Finding out about the order of events, or comparing the ages of rocks without actually knowing their age in years, is called **relative dating**.

Fossil of a reptile



1. Conglomerate was deposited first in this rock sample. This layer was deposited by a glacier or an active environment — such as a very fast flowing river.
2. This is the second layer deposited. Shale is a fine-grained rock that is deposited in a quiet environment such as a swamp, lake or the slow-flowing part of a river.
3. The third event to occur was the deposition of limestone. It tells us that there were probably marine organisms present in the area during this time.
4. A slow event caused the lower levels to buckle. This is called **folding**. Folding can occur when rock layers are under pressure from both sides.
5. A sudden event, such as an earthquake, occurred to break the layers of rocks like this. This event took place after the lower layers were folded. A break like this is called a **fault**.
6. A long period of weathering and erosion left the layer of limestone with a flat surface. When a volcano then erupted nearby, lava from the volcano cooled to form basalt on the flat surface.
7. These layers were deposited last. They have started to weather and erode.



Palaeontologists study **fossils**. A fossil is evidence of life in the past. Fossils can be used to compare the ages of rocks all around the world. Sedimentary rocks that contain the same fossils usually formed at about the same time.

10.6.3 How fossils form

Scientists measure a 2.3-metre-long sauropod bone found in France.



The remains of most animals and plants decay or are eaten by other organisms, leaving no trace behind. However, if the remains are buried in sediments before they disappear, they can be preserved, or fossilised. Fossils can take several forms.

- The hard parts of plants and animals are more likely to be preserved than the softer parts. Wood, shells, bones and teeth can be replaced or chemically changed by minerals dissolved in the water that seeps into them. Fossils formed in this way are the same shape as the original remains but are made of different chemicals; petrified wood is an example. Animal bones and shells can be preserved in sediments or rock for many years without changing. The types of bones, shells and other remains found in the layers of sedimentary rock provide clues about the environment, behaviour and diets of ancient animals.
- Sometimes, fossils of whole organisms, including the soft parts, are preserved. Such fossils are rare and valuable. Insects have sometimes been preserved whole as a result of being trapped in the sap of ancient trees. Over millions of years, the sap has petrified to form amber. Similarly, if the remains of animals or plants are frozen and buried in ice, they can be fully preserved. Whole bodies of ancient woolly mammoths (including skin, hair and internal organs) have been found trapped in the ice of Siberia and Alaska. These remains provide clues to the way that living things have changed since ancient times. Whole bodies and preserved skulls of animals can even reveal evidence of their last meal before death.
- The remains of animals or plants sometimes leave an impression, or imprint, in hardened sediments or newly formed rock. It is also possible for remains trapped in rock to be broken down by minerals in water, leaving a **mould** in the shape of the organism.
- Some fossils, called **trace fossils**, provide only signs of the presence of animals or plants. For example, footprints preserved in rock can provide clues about ancient animals, including dinosaurs, and how they lived. By studying the shape, size and depth of footprints, hypotheses can be made about the size and weight of extinct animals as well as how they walked or ran. Plant, leaf and root imprints and feather impressions are other examples of trace fossils.

These insects were trapped in the sap of a tree millions of years ago.



INVESTIGATION 10.6

Making a fossil

AIM: To demonstrate the process of fossilisation

You will need:

small seashell
small box (shoebox or milk carton)
fine sand
plaster of Paris

- Half-fill the box with fine, damp sand.
- Make a clear imprint of a small seashell in the sand.
- Mix some plaster of Paris and pour it carefully into the imprint.
- Once the plaster has set, remove the plaster cast carefully from the sand.
- You have two records of the seashell — the mould or imprint in the sand and the plaster cast.

Discussion

1. Which parts of animals are most likely to be preserved as casts?
2. Is the fossil of a fern leaf more likely to be found as a cast or a mould? Why?
3. Dinosaur fossils are found in casts and moulds. What evidence of dinosaurs is likely to be found as a mould?

CAUTION: Do not put plaster of Paris down the sink.

Paleontologists have been able to study the well-preserved body of this baby mammoth. This 40 000-year-old, whole-body fossil was found by a hunter in the Russian arctic in 2007.

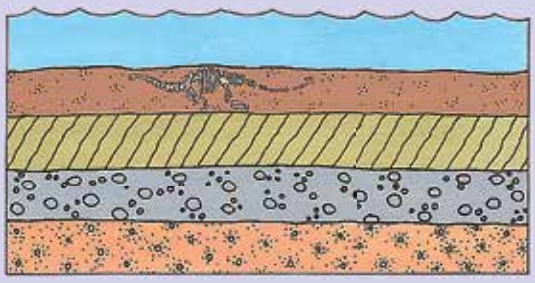


10.6.4 Dinosaurs preserved in rock

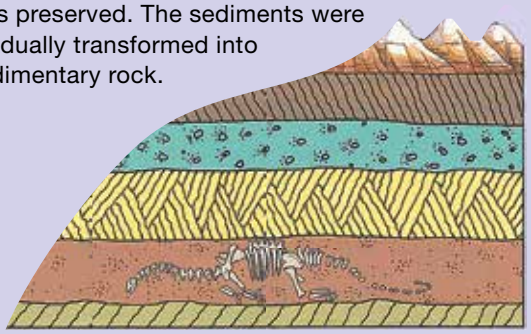
1. After the death of a dinosaur, its body would usually be eaten by meat-eating animals (**carnivores** or **scavengers**). Its bones would be crushed or weathered, leaving no remains. If, however, the remains of a dinosaur were buried in sediment, the bones could be preserved.



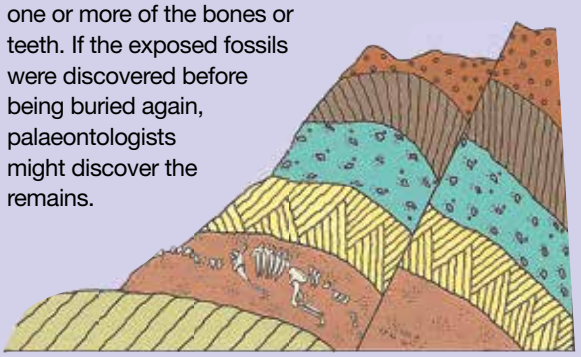
2. If a dinosaur died near a muddy swamp, shallow lake or riverbed, its remains sank in the mud or were washed into a river in a flood. The bones were quickly buried in sediment.



3. Over millions of years, more layers of sediment were deposited on top of the buried remains. Chemicals dissolved in the water that seeped into the remains changed their colour and chemical composition. The shape, however, was preserved. The sediments were gradually transformed into sedimentary rock.



4. The layers of rock containing the fossilised remains were pushed upwards, bent and tilted by forces beneath the Earth's surface. Weathering and erosion by the wind, sea, rivers or glaciers might expose one or more of the bones or teeth. If the exposed fossils were discovered before being buried again, palaeontologists might discover the remains.

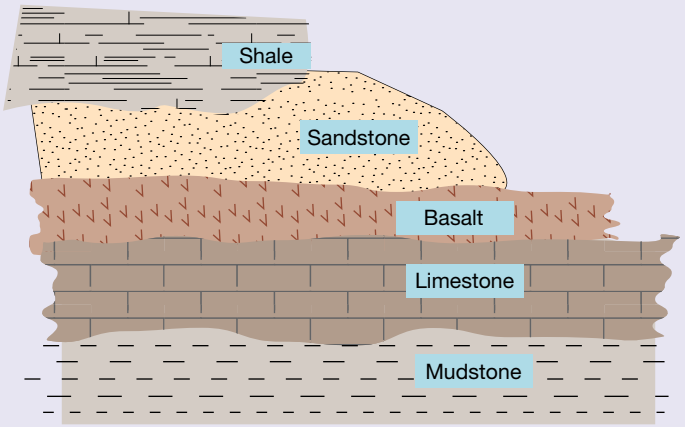


10.6 Exercise: Remember and think

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Remember

Layers of rock exposed by a road cutting

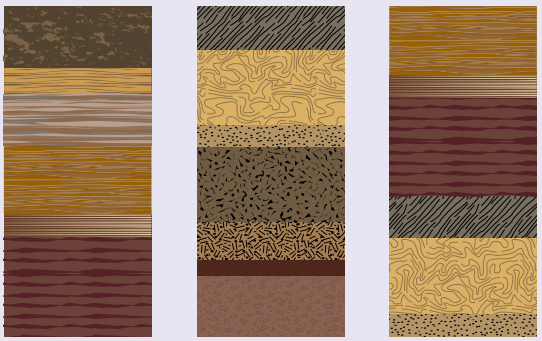


1. A road cutting reveals the layers of rock shown at right. **Identify** which of the rocks in the cutting is:
   (a) the oldest rock
   (b) the youngest rock
   (c) evidence of volcanic activity
   (d) not a sedimentary rock.
2. **Recall** why some layers of sedimentary rock are tilted, even though the sediments that formed them were laid in horizontal beds.
3. **Distinguish** between the relative age of a rock and its actual age in years.
4. **Recall** what a palaeontologist studies.
5. **Describe** the clues that fossils provide about life in the past.
6. **Describe** how whole ancient living things can be preserved as fossils.
7. **Define** the term 'trace fossils', and **explain** how they are useful.
8. **Distinguish** between a cast and a mould.
9. List the information about dinosaurs that can be obtained from fossils.

Think

10. Fossils of dinosaurs formed when their remains were buried under many layers of rock. **Explain** why fossils are often discovered in rocks and soil on the surface.
11. **Explain** how it is possible to use preserved dinosaur footprints to form hypotheses about:
    (a) whether dinosaurs lived alone or in herds
    (b) the way dinosaurs walked
    (c) the weight of different kinds of dinosaurs
    (d) the walking or running speed of dinosaurs.
12. **Identify** which of the rocks in the diagram in question 1 would be most likely to contain the fossil of:
    (a) a seashell
    (b) the leaf of a fern usually found in swamps.
13. **Explain** why some layers shown in the diagram in question 1 are thicker than others.

14. **Explain** why the hard parts of plants and animals are more likely to be preserved than the softer parts.
15. Is an ancient Egyptian mummy found in a newly discovered tomb a fossil? **Explain** your answer.
16. Normally, older layers of rock are found below younger layers. Sometimes, however, younger layers are found beneath older layers. **Deduce** how this could happen.
17. **Describe** how fossil records can help us to link rocks from different parts of the world.
18. Examine the diagrams at right, which show cross-sections of an archaeological dig in three different locations in the same general area. Decide which cross-section of strata — A, B or C — is likely to contain (a) the oldest remains, and (b) the most recent remains.



Create

19. Use plasticine to **construct** a sample of sedimentary rocks. Apply a gentle force to the sides of the layers. **Describe** how the layers fold under gentle pressure.

Investigate

20. Even an animal's droppings can become fossilised. Use the internet or your library to **investigate** the following.
    (a) Which animal was responsible for a huge fossilised dropping found in Canada in 1998?
    (b) How long was the dropping?
    (c) What can palaeontologists find out from it?
    (d) Scientists give fossilised droppings a special name. What is it?
21. Find out how the actual age of a rock in years is determined. This actual age is known as the **absolute age**.
22. Rate the rock formations in order from the oldest to the most recent with the **Relative age of rocks** interactivity in the Resources tab. **int-0233**

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Complete this digital doc: Worksheet 10.5: Tracking changes in rock (doc-12432)

Try out this interactivity: Relative age of rocks (int-0233)

10.7 Rocky changes

10.7.1 Metamorphic rocks

Sedimentary rocks are those that have formed from deposits of weathered rock or the remains of living things.

Igneous and sedimentary rocks deep below the Earth's surface are buried under the huge weight of the rocks, sediments and soil above them. They are also subjected to high temperatures. The temperature increases by about 25 °C for every kilometre below the surface. This heat and pressure can change the composition and appearance of the minerals in rocks.

Gneiss is formed mainly as a result of great pressure on granite.



The process of change in rocks is called **metamorphism** and the rocks that are formed by these changes are called **metamorphic rocks**. The name for these changed rocks comes from the Greek words *meta*, meaning 'after' or 'changed' and *morphe*, meaning 'form'.

The changes that take place during the formation of metamorphic rocks depend on:

- the type of original rock
- the amount of heat that the original rock is exposed to
- the amount of pressure caused by the weight of the rocks above
- how quickly the changes take place.

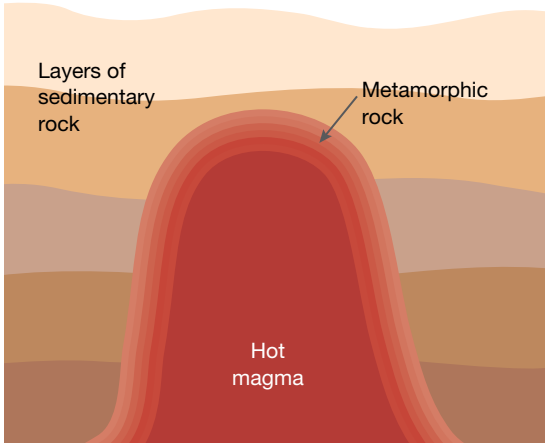
Metamorphic rocks that are mainly the result of great pressure can often be identified by bands or flat, leaf-like layers. These bands are evident in the sample of gneiss (pronounced 'nice') pictured above. The diagram at right shows how rocks can be changed by the high temperatures that result from contact with hot magma.

Other common examples of the formation of metamorphic rocks are:

Shale (sedimentary)	mainly pressure ⇒	Slate
Sandstone (sedimentary)	mainly heat ⇒	Quartzite
Limestone (sedimentary)	mainly heat ⇒	Marble

The nature of metamorphic rocks above and below the ground can provide clues about the history of an area.

The formation of metamorphic rock by contact with hot magma



Marble forms from limestone under heat and pressure. It contains the same minerals as limestone.



The presence of slate might suggest that the area was once the floor of a still lake or river mouth. The sediments were probably buried under many other sediments and cemented together to form shale. The shale was transformed, or metamorphosed, into slate as a result of new rock formed above it. Think about why the presence of quartzite or marble high in a mountain range would suggest that the area was once below the sea.

Shale is a common type of sedimentary rock. It has fine grains and crumbles easily along its layers. When shale is exposed to moderate heat and pressure, it forms slate.



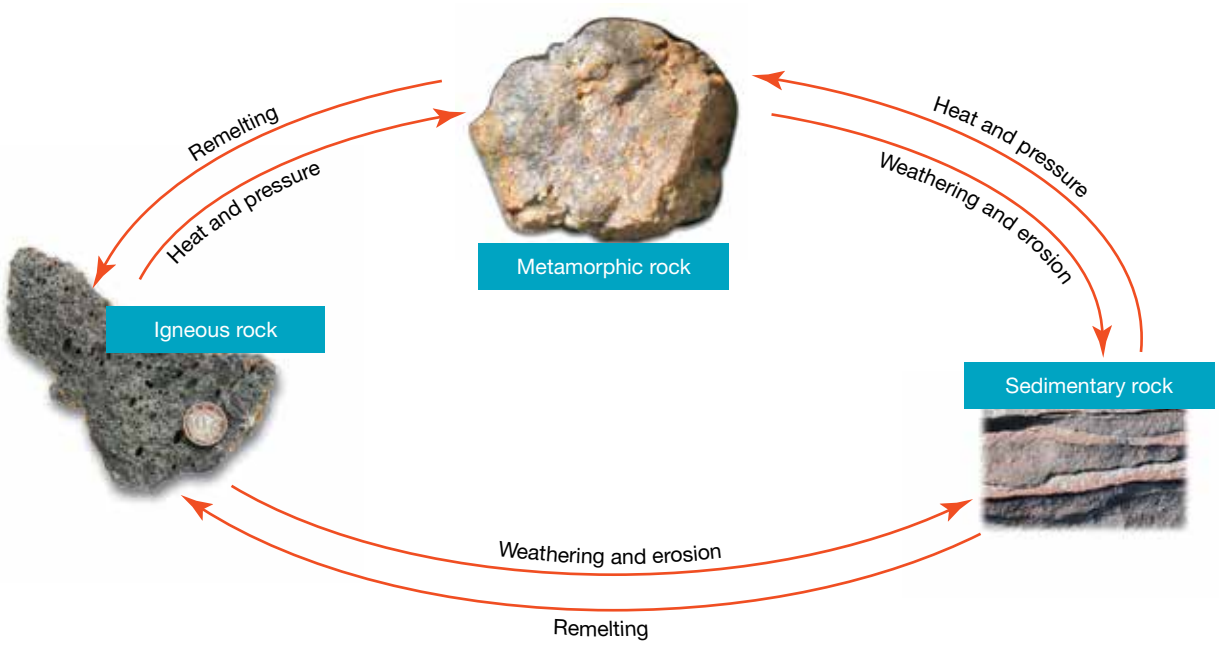
HOW ABOUT THAT!

Have you ever tried to lift one end of a pool and noticed how incredibly heavy it is? It's really heavy because the flat surface under the felt is not wood as you may have thought — it's actually made of slate. Because of its natural hardness and its flat face, it makes an ideal even surface!



10.7.2 The rock cycle

The rock cycle describes how rocks can change from one type to another. Weathering, erosion, heat, pressure and remelting are processes that help change rocks. The rock cycle is different from other cycles because there is no particular order in which the changes happen. Some rocks have been unchanged on Earth for millions of years and may not change for millions more. Some rocks change very quickly, especially near the edges of the plates that make up the Earth's crust.



HOW ABOUT THAT!

A tadpole grows into a frog, female frogs lay eggs, and eventually more tadpoles emerge from the eggs. That's a life cycle. Some of the changes in rocks can be described as cycles too. Weathered rock is moved by erosion and the particles form sediments, which can be cemented together to form sedimentary rocks, which in turn may eventually change into metamorphic rocks. Once those rocks are exposed at the surface, the weathering starts all over again. A complete cycle normally takes millions of years, but sometimes never takes place at all. Why?

There are many cycles in nature. Some happen faster than others.



INVESTIGATION 10.7

Rocks — the new generation

AIM: To examine 'parent' and metamorphic rock

You will need:

labelled rock samples including:
- *granite*
- *gneiss*
- *limestone*
- *marble*
- *sandstone*
- *quartzite*
- *shale*
- *slate*

hand lens

- Try to sort the rocks into pairs of 'parent' rock and corresponding metamorphic rock. Use the examples on the beginning of this section if you have trouble pairing the rocks.
- Examine each pair of rocks with a hand lens.
- Copy and complete the table below by noting the similarities and differences between the 'parent' and metamorphic rock of each pair.

Discussion

1. Why is the term 'parent' rock used?
2. Use the last column of your table to suggest whether the main cause of metamorphism was heat or pressure.

Comparing 'parent' and metamorphic rocks

'Parent' rock	Metamorphic rock	Similarities	Differences	Main cause of metamorphism
Shale				
	Gneiss			
Sandstone				
	Marble			

10.7 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. Rocks are classified into three groups. Metamorphic rocks make up one of these. **Identify** the two groups of rock that metamorphic rocks are formed from.
2. **Recall** the processes that can cause rocks to change form and become metamorphic rocks.
3. **Describe** how the appearance of gneiss differs from granite.
4. **Recall** how granite can be transformed into gneiss.
5. **Explain** why slate is commonly used in floor tiles.
6. When sandstone is under heat and pressure, **identify** which metamorphic rock it might form.
7. **Identify** the rock type that slate is formed from.
8. **Classify** the following rocks as sedimentary, igneous or metamorphic.
   (a) Sandstone
   (b) Marble
   (c) Basalt
   (d) Gneiss
   (e) Granite

Think

9. **Explain** what the bands in metamorphic rocks tell us about how the rocks were formed.
10. If an igneous or a sedimentary rock gets so hot that it melts completely, it does not become a metamorphic rock. **Explain** why.
11. **Deduce** why geologists describe limestone as the 'parent' rock of marble.
12. Metamorphic rocks are generally formed deep below the surface of the Earth. However, they are often found above the ground — even high in mountain ranges. **Explain** how this can be so.
13. Limestone is a sedimentary rock. **Describe** the events that could occur to change limestone into another rock.

Investigate

14. **Investigate** the uses of marble and slate. Where are they obtained? What are they used for? Why are they expensive?
15. Apply mainly heat or pressure to a series of rocks and watch them change with the **Metamorphic rocks** interactivity in the Resources tab. **int-0234**
16. Use the **Rock cycle** weblink in the Resources tab to watch an animation of how rocks undergo change.

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Complete this digital doc: Worksheet 10.6: The rock cycle (doc-12433)

Explore more with this weblink: Rock cycle

Try out this interactivity: Metamorphic rocks (int-0234)

10.8 Human-made erosion

Science as a human endeavour

10.8.1 Why save the trees?



Without weathering and erosion, the rocks that rise to the Earth's surface would keep building up. Both weathering and erosion are natural processes. But what happens when humans disturb the natural process?

Imagine a world where acid falls from the sky, a place where deserts replace fertile land and where the beaches are vanishing. These are some of the effects that humans have already had on the Earth.

The roots of trees help to hold the soil together. Removing trees exposes good, fertile soil to wind and water. The soil is blown or washed away, leaving the land destroyed. Early Australian settlers originally cut down trees to create farmland. As the population grew, more trees were cleared to provide space for industrial areas and housing. Since then, industrial areas have grown larger and the forests smaller. Trees are still being cleared for wood and wood products like paper (see the photo on the next page).

Over the past 200 years, over two-thirds of Australian forests have been cleared.

10.8.2 Coasts under threat

Coastal areas can be badly affected by erosion. Bare sand is easily washed away by water and blown inland by the wind. Vegetation that binds the sand together has been torn up by recreational vehicles. Vegetation near beaches in tourist areas such as the Gold Coast has been removed and replaced with huge buildings. Barriers such as sea walls, mesh fences and **groynes** then had to be built to hold sand on the beaches.



On the mend

Scientists, conservation groups and government bodies play an important part in improving the environment. The aim is to reduce the impact of human activity and repair past damage. Some methods of reducing erosion and repairing the damage already caused by erosion include:

- farmers ploughing their fields around hills rather than up and down the slope. This reduces the amount of soil washed down hills by rain.
- sealing roads and gutters to direct water into proper drains
- controlling numbers of livestock
- replacing trees that have been removed
- fencing off large sections of beaches and banning recreational vehicles in many coastal areas
- reducing the impact of introduced animals, such as rabbits, on native vegetation.

INVESTIGATION 10.8

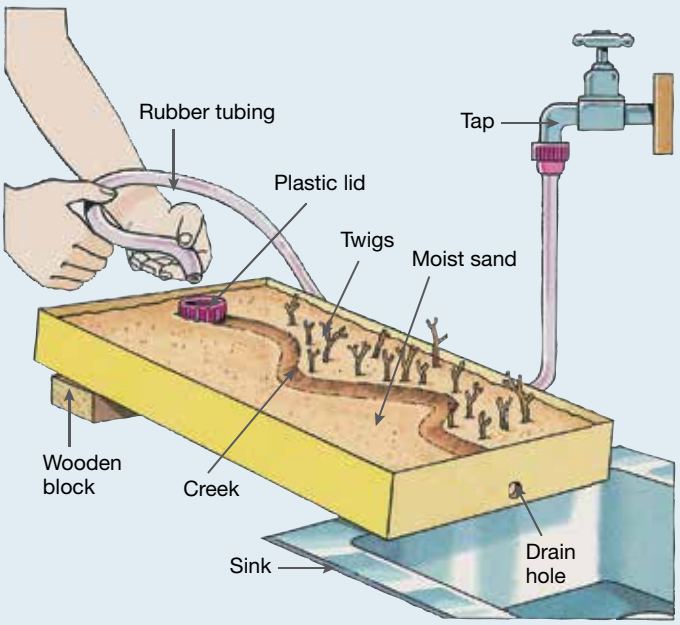
Why plant trees?

AIM: To demonstrate the effect of land clearing

You will need:

stream tray or box
damp sand
wooden block
rubber tubing
plastic lid from a soft-drink bottle
several small twigs

- Pack the sand into the tray.
- Make a groove in the sand to represent a creek or river.
- Set up the equipment as shown in the diagram.
- Make sure to 'plant trees' on one side of the 'creek' only.
- Use the rubber tubing to aim water into the lid.
- Allow water to flow slowly but steadily into the lid and then overflow into the 'creek'.



Discussion

1. Where does most of the erosion occur along the 'creek'?
2. What effect do the 'trees' have on erosion?

HOW ABOUT THAT!

Every day many harmful chemicals are pumped into the air. Some are naturally formed chemicals, but many are from cars, factories or from other human activity. The chemicals in the air can dissolve in water, much like salt in hot water. The dissolved chemicals return to the ground in rainwater, snow or fog, and the combination is called acid rain.

Acid rain can poison trees, soil and water supplies. It even eats away at rocks, including those used in buildings and statues.



10.8 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 term 'acid rain'.
2. Give two reasons why forests have been cut down.
3. **Explain** how cutting down trees speeds up erosion.
4. **Describe** two ways that farmers can reduce erosion.

Think

5. **Explain** why a barrier has been placed at the back of the beach in the photo on page 404.
6. The photograph at right shows an example of tunnel erosion. **Suggest** what has caused the erosion and how it may be stopped.



Create

7. **Construct** a flow chart to show how deforestation can occur.

Discuss

8. Imagine you work for a local council in an area that has both national parks and coastlines. Your job is to educate people in the area about erosion and land care. Design and **construct** a leaflet that gives reasons for not using recreational vehicles in the area.

10.9 Review

10.9.1 Study checklist

Rock composition

- **describe** the lithosphere 10.2
- **recall** that all rocks are made up of minerals 10.2
- **identify** minerals based upon their hardness, lustre, colour and streak 10.2
- **define** the Mohs' hardness scale 10.2

Types of rock

- **distinguish** between extrusive and intrusive igneous rocks 10.3
- **explain** the differences between igneous, sedimentary and metamorphic rocks 10.3, 10.5, 10.7
- **describe** how metamorphic rocks are formed from sedimentary and igneous rocks 10.7
- **identify** a variety of igneous, sedimentary and metamorphic rocks 10.3, 10.5, 10.7
- **recall** how crystal size depends on cooling rate 10.3
- **explain** how crystals can be used to identify rock types 10.3
- **describe** the rock cycle 10.7
- **explain** how rock layers reveal information about changes to the Earth 10.5–10.7

Fossils

- **describe** the work of paleontologists 10.6
- **recall** the different types of fossils and explain how they may be formed 10.6
- **explain** why fossils may be preserved in sedimentary rock rather than igneous rock 10.6
- **explain** how the ages of fossils can be determined using rock layers 10.6

Weathering

- **define** the terms 'weathering', 'erosion' and 'sediment' 10.4, 10.5
- **recall** different ways that sediment may be deposited 10.4
- **explain** how acid rain affects rocks and human-made structures 10.8
- **identify** Australian examples of rock formations that have been created by erosion and weathering 10.4
- **describe** the effect of deforestation on soil erosion 10.8
- **describe** methods that can be used to reduce soil erosion 10.8

Individual pathways

ACTIVITY 10.1
Revising the changing Earth
doc-10565

ACTIVITY 10.2
Investigating the changing Earth
doc-10566

ACTIVITY 10.3
Investigating the changing Earth further
doc-10567

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FOCUS ACTIVITY

online only

Research and report on a range of tools, weapons and other devices made of rock used by Aboriginal and Torres Strait Islander peoples.

Access more details about focus activities for this topic in the Resources tab (doc-10564).

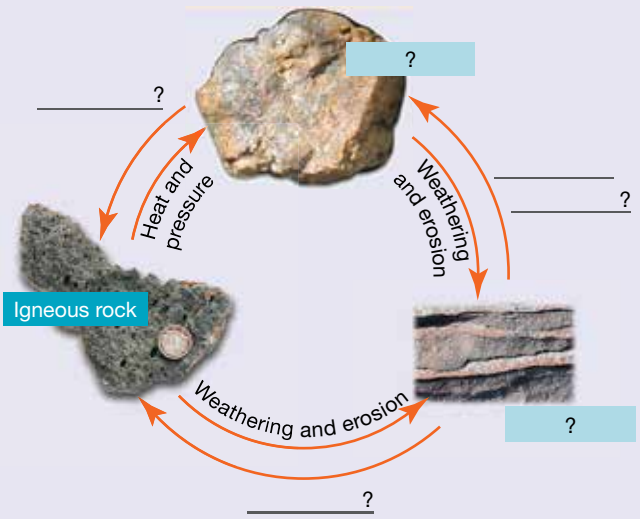
10.9 Review 1: Looking back

assessON

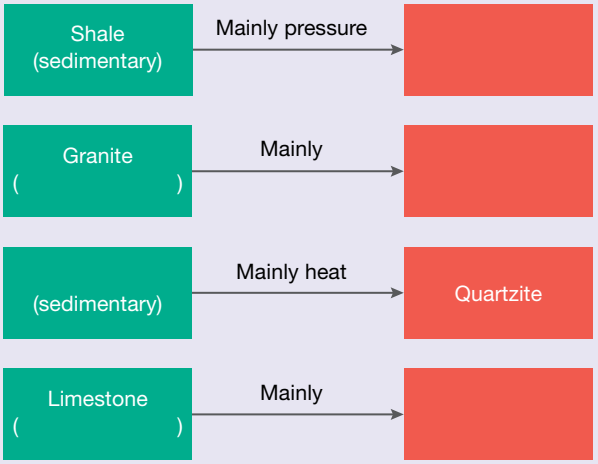
1. **Identify** which of the following are extrusive igneous rocks and which are intrusive igneous rocks: scoria, basalt, granite, obsidian, pumice.
2. What information can be determined by examining the crystals of rock minerals?
3. **Explain** how the lithosphere differs from the crust.
4. **Evaluate** whether the word in italics makes the statement true or false. If the statement is false, replace the word in *italics* to make it true.
   (a) Extrusive rocks form *above* the Earth's surface.
   (b) The *faster* the cooling time, the larger the crystal size in igneous rocks.
   (c) *Weathering* is the process of moving broken down rock or soil from one place to another.
5. Often, when lava cools, the rocks formed near the edge of the lava flow have different-sized crystals from the rocks formed in the middle of the flow.
   (a) **Describe** where in the flow the rocks with the smallest crystals would form.
   (b) **Propose** a reason for this.
6. Draw diagrams to **explain** the difference between weathering and erosion.
7. While studying sedimentary rocks in a railway cutting, a geologist discovers a bed of rock with ripple marks in its surface. How could the ripple marks have been made in the rock?
8. **Define** the term 'parent rock'.
9. There is a lot of evidence that the Earth is changing. Volcanoes erupt, coastlines disappear, cracks appear in the ground, and fossils of seashells can be found on the top of some high mountains. In some cases, ancient cities have been found beneath the sea. Some of these changes are caused by natural events that shape the Earth over millions of years; other natural events happen very quickly, in days, hours, minutes or even seconds. Unfortunately, not all of the events that change the surface of the Earth are natural. Some of them are caused by human interference with the environment.
   (a) Copy and complete the following table, which lists some of the natural events that change the Earth. Work in a small group to add as many natural events to the table as you can.
   (b) Work in a group to **construct** a table like the one below that lists non-natural events that shape the Earth or might shape the Earth in the future.

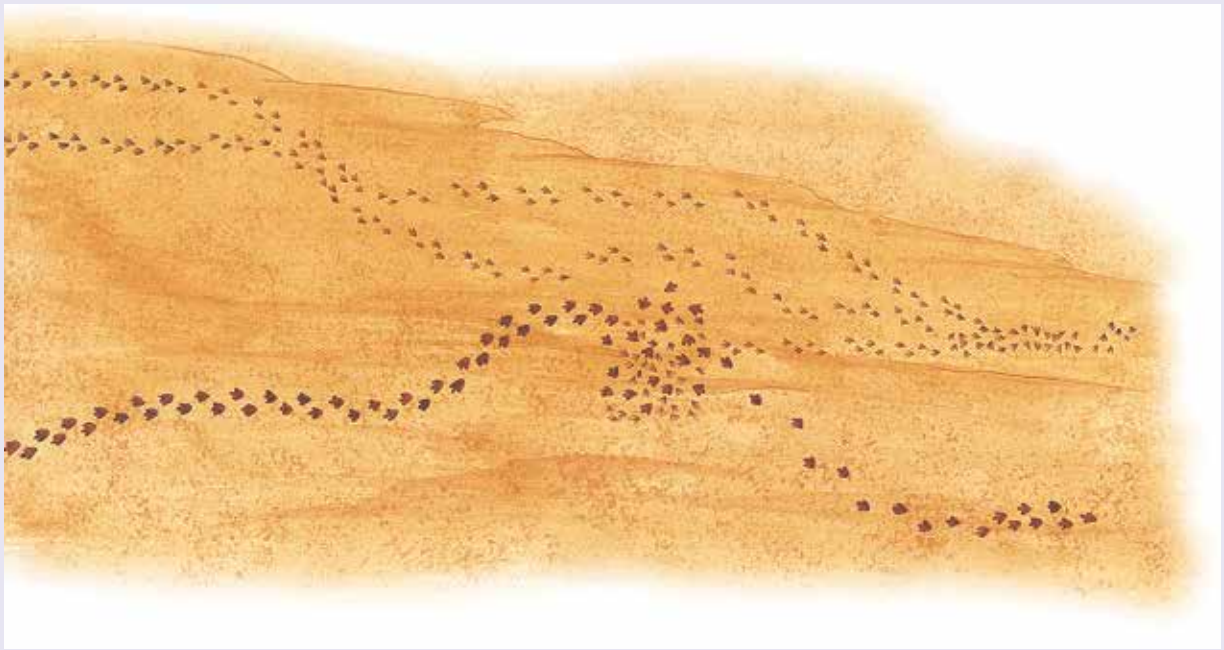
Natural event	Conditions that cause the event	Likely effects on the Earth's surface or crust	Likely effects on humans
Cyclone			
Earthquake			
Volcanic erruption			
Drought			
Tsunami			
Erosion			

   (c) For each of the events that you have included in your table for part (b), **describe**:
      (i) whether the changes made to the Earth's surface would continue to have effects if humans were to suddenly be removed from the planet
      (ii) ways in which these events could be stopped.
10. Fill in the blanks in the diagram at right.



11. **Explain** why acid rain eats away some types of stone used in buildings, but not others.
12. Copy and complete the diagram below to show how some common metamorphic rocks are formed.





13. Imagine that the set of fossilised dinosaur footprints shown in the illustration above were found in a layer of sedimentary rock.
    (a) Use the footprints to write a description of what might have happened millions of years ago.
    (b) **Compare** your interpretation of the footprints with others.
    (c) Does each person **interpret** the evidence in the same way?
    (d) If there are differences of opinion about what happened, is there any way of knowing who is right?
    (e) List as many differences as you can between the two types of dinosaurs making these footprints.
14. Not all fossils are the actual remains of living things. Name and **describe** two types of fossils that are not preserved remains.
15. Normally, old layers of rock are found below younger layers. Sometimes, however, younger layers are found beneath older layers. **Explain** how this could happen.
16. Deforestation is a worldwide problem.
    (a) **Describe** how deforestation speeds up the processes of weathering and erosion.
    (b) **Recall** some measures that are being taken to reduce erosion and improve the environment.

17. The photograph at right is of a giant dinosaur footprint that has been preserved in rock at Lark Quarry in central Queensland.
    (a) What type of fossil is it?
    (b) Why is it classified as a fossil even though it could be described as a dent in a rock?
    (c) Have all dinosaur footprints been preserved? Why has this one been preserved for hundreds of millions of years?
    (d) What can be learned about the features of the dinosaur that left this footprint?
    (e) What forms of evidence, apart from preserved footprints, can be used to gather knowledge about dinosaurs?



18. The Grand Canyon in Arizona, shown below right, has been forming over millions of years. It once formed the lower slopes of a mountain range that was twice as high as Mount Everest. Today, it is the largest gorge on Earth. The Colorado River flows in the bottom of the gorge.
    (a) **Describe** how the gorge was probably formed.
    (b) State what types of rock would be found here and **explain** your answers.



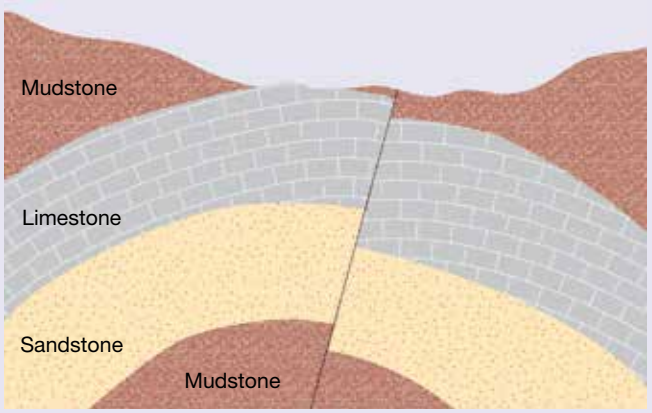
19. **Identify** the following rocks based on their descriptions:
    (a) This rock is deposited in layers that are squashed together over long periods of time. It is most easily seen in road cuttings or cliff faces.
    (b) This rock is formed from limestone that has been heated and placed under great pressure. It is very hard but is able to be formed into sculptures.
    (c) This igneous rock is speckled in appearance due to its large crystals of feldspar, mica and quartz.
    (d) This dark, glassy rock is formed from the same material as basalt but has no crystals.
    (e) This is a pale rock that has a lot of holes in it. It can float on water and is used as an abrasive.

Test yourself

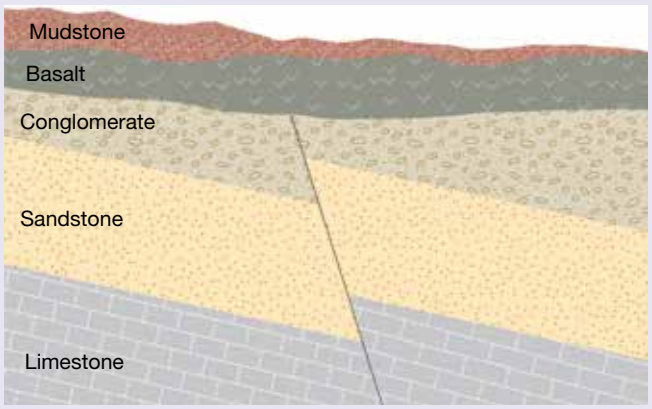
1. Rocks that have formed from cooled lava are described as
   (A) plutonic.
   (B) igneous.
   (C) metamorphic.
   (D) sedimentary.

(1 mark)

2. Fossils are most likely found in
   (A) granite.
   (B) basalt.
   (C) obsidian.
   (D) shale. **(1 mark)**
3. The lithosphere includes the
   (A) crust and the upper sections of the mantle.
   (B) crust only.
   (C) mantle only.
   (D) top layer of the crust only. **(1 mark)**
4. The hardest mineral on Mohs' scale of hardness is
   (A) talc.
   (B) quartz.
   (C) corundum.
   (D) diamond. **(1 mark)**
5. **Describe** the order of events that occurred to form these rock samples.
   (A) **(3 marks)**



   (B) **(3 marks)**



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Complete this digital doc: Worksheet 10.8: The changing Earth puzzles (doc-12434)

Complete this digital doc: Worksheet 10.9: The changing Earth summary (doc-12435)

TOPIC 11
Energy

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?

Fireworks are noisy, colourful and bright. They contain a fuel that explodes when ignited, creating a loud explosion. Powdered metals are included in the mixture of explosives to produce the brightly coloured sparks we see.

Energy transformations take place when fireworks explode, producing sound and light.

LEARNING SEQUENCE

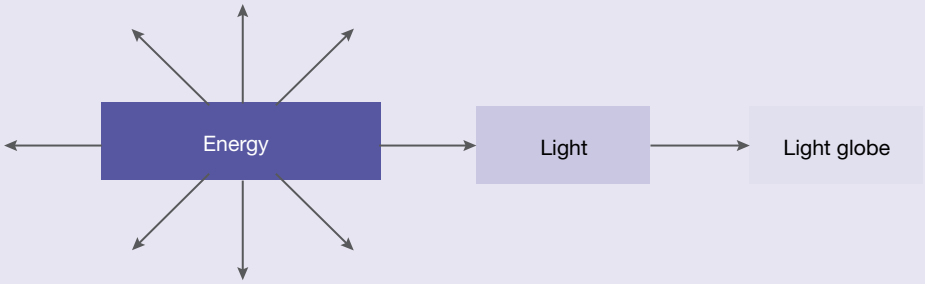
11.1 Overview	412
11.2 Energy transfers and transformations	414
11.3 Heat and temperature	420
11.4 Using electrical energy	430
11.5 Technological solutions to energy efficiency	444
11.6 Going green	452
11.7 Review	454

Fireworks display over Sydney during New Year's Eve celebrations



Thinking about energy

1. In groups create a mind map around the central theme of energy. Begin by brainstorming different types of energy. Then continue your mind map outwards to include examples of devices that use or release each type of energy. The mind map has been started for you.



2. Conduct an audit of your house. Walk around the house and speak to your parents to list features that keep your house:
   - cool in summer
   - warm in winter.
3. If you were to renovate your house, what features would you add to improve how well it keeps you cool in summer and warm in winter?
4. You have 100 mL of water in a beaker at 20 °C and a second beaker with 100 mL of water at 80 °C. Predict what would happen if you combine the two samples in the same beaker. Test your prediction by carrying out this experiment.
5. Draw up a table with two columns. In the first column, list objects that give out light. In the second column, outline how the light is produced or identify the source of energy.
6. Take a look at the light globes used in your home. Do they get hot after they have been switched on for a while? Why might compact fluorescent light globes be increasing in popularity?
7. The two photos below show houses designed for a hot climate and a cold climate. Identify which is suited to which climate. Compare the two houses by listing features of each that make them suited to their respective climates.





11.2 Energy transfers and transformations

11.2.1 What is energy?

Have you ever felt like you were 'full of energy'? If so, you probably felt like moving around or doing something active. Objects can have energy too. We cannot always see the energy that they possess, but we can often observe the effects of objects gaining or losing energy. Winding up a toy or pulling back the string of an archery bow gives these objects lots of energy.

Energy is defined as the ability to do work.

Energy may cause an object or other nearby objects to move, such as winding up a toy or firing an arrow from a stretched bow. The energy of an object can also give objects the potential to move or to create sound, heat or light.

Types of energy

There are different types of energy that an object might possess. One common type of energy is **kinetic energy**. All objects that are moving have kinetic energy. The faster an object moves, the more kinetic energy it has. Kinetic energy depends on the mass of the moving object; a heavy truck travelling at 60 kilometres per hour has more kinetic energy than a lighter car travelling at the same speed. Moving objects can do work by travelling distances or by colliding or pushing other objects.

Another common type of energy is **gravitational energy**. Objects above the ground have gravitational energy because the Earth's gravitational force can cause them to fall to Earth. The higher an object, the more gravitational energy it has.

Often, objects with gravitational energy do not appear to have any energy at all, particularly if they are not moving. However, they still have the potential to do work and so the energy is 'stored'. Gravitational energy is an example of **potential energy**. Pole vaulters at the top of their jump have a great deal of gravitational potential energy that is transformed to kinetic

Winding up a toy or pulling back the string of an archer's bow provides these devices with energy to move and do work.





energy as the vaulter falls back to the ground. Other examples of potential energy are elastic energy (such as when a rubber band is stretched), nuclear energy (such as that in a nuclear bomb) and chemical energy (evident in chemical reactions).

Many other types of energy are important in our daily lives. These include sound energy, heat energy, light energy and electrical energy.

Objects at a height above the ground have stored energy called gravitational potential energy. The higher an object is, the more gravitational potential energy it has.



11.2.2 How much energy?

Energy is measured in a unit called the joule (J), named after the British physicist James Joule (1818–1889). The kinetic and gravitational potential energy of objects can be calculated using a couple of simple formulae.

Calculating gravitational potential energy

Gravitational potential energy of an object = mgh where:

- m represents the mass of the object (in kilograms)
- g represents the object's gravitational acceleration when falling (10 metres/second^2 on Earth)
- h represents the object's vertical height (in metres).

For example, to calculate the potential energy of an 80 kg skier on a chairlift 20 m off the ground:

potential energy = 80 kilograms × 10 m/s^2 × 20 m
= 16 000 joules or 16 kilojoules

Calculating kinetic energy

Kinetic energy of a moving object = $\frac{1}{2}mv^2$ where:

- m represents the mass of the moving object (in kilograms)
- v represents the object's speed (in metres/second).

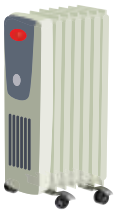
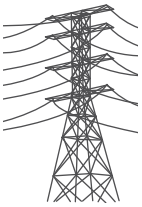
For example, to calculate the kinetic energy of a cyclist and bicycle with a total mass of 100 kg travelling at 5 *m*/*s*:

kinetic energy = $\frac{1}{2}$ × 100 kg × (5 m/s)^2
= 1250 joules or 1.25 kilojoules

11.2.3 Transferring and transforming energy

Energy can be **transferred**, or passed on, to another object or to the surrounding environment. For example, if you hug a hot-water bottle, the heat is transferred from the bottle to you. The heat has been transferred from one object to another, but has not changed form.

Energy can also be **transformed** or converted into other forms of energy. For example, the electric motor in a hair dryer transforms electrical energy into kinetic energy: that is, the energy of the moving fan blades. Sometimes, during a transformation of energy, not all of the energy is transformed into useful forms. Some of the energy may be transferred to the surrounding environment as unwanted heat, or transformed to light or sound. For example, not all of the energy you use to ride a bike up a very steep hill goes into making the pedals move. Some of the energy is 'wasted' as your body gives off heat, or as heat is produced by friction in the gears.

Types of energy			
Potential energy (stored energy that, when released, is converted to other forms such as sound, heat or light energy)		**Other types of energy** (often converted from potential energy, these are more easily observed by our senses)	
Gravitational (potential energy of an object elevated above the ground)		**Kinetic** (energy possessed by objects that are moving)	
Elastic (energy stored by an elastic object that is stretched, such as a spring or rubber band)		**Heat** (energy that causes objects to gain temperature)	
Chemical (energy stored in chemicals that, when reacted together such as in burning reactions, release heat, sound or light)		**Light** (energy that may be released, for example, when an object is hot or by a nuclear reaction in a star)	
Nuclear (energy stored in the nucleus of atoms that can release energy slowly, such as in a nuclear reactor, or quickly, such as in a nuclear explosion)		**Sound** (energy carried by the air in a room and detected by the ear)	
Electrical (energy supplied to homes by powerlines and available to your appliances via power outlets in the home)			

The chemical energy in household batteries is an example of potential energy that powers many household devices, including remote controls.



All objects that are moving have kinetic energy. The faster an object moves, the more kinetic energy it has. Moving objects can do work by travelling distances or by colliding with other objects.



Types of energy changes involved in bouncing on a trampoline

1. At the very top of a jump, the bouncer is momentarily stopped — she has no kinetic energy. But she does have gravitational potential energy due to her height above the trampoline. As the force of gravity pulls the bouncer down, some of her potential energy is transformed into kinetic energy.



2. As the bouncer strikes the trampoline, her kinetic and gravitational potential energy cause the trampoline's surface and springs to stretch. The energy is momentarily stored as **elastic potential energy**.



3. At this point, the bouncer pushes off the trampoline. The elastic potential energy is transformed back into kinetic energy and some gravitational potential energy.



4. As the bouncer rises, her kinetic energy is transformed into gravitational potential energy again. At the top of the jump, the bouncer has no kinetic energy, just gravitational potential energy.



A clock radio *transforms* electrical energy into sound energy when the alarm or radio is heard and into light energy in the time display.



THE LAW OF CONSERVATION OF ENERGY

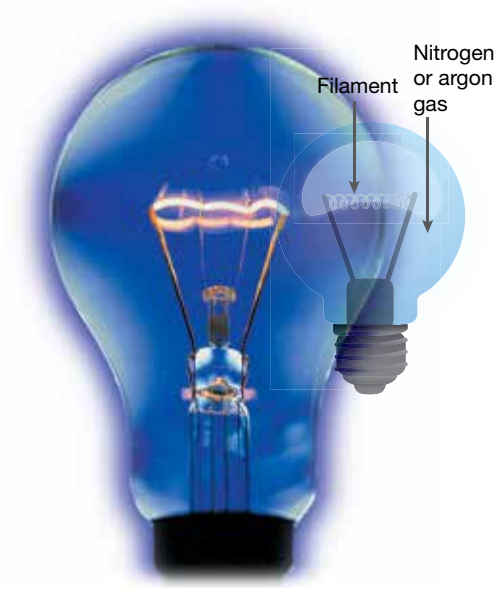
When objects stop moving, they no longer have kinetic energy. But the energy is not lost. Instead, it is converted (transformed) into another type of energy or passed on (transferred) to another object. The Law of Conservation of Energy tells us that the amount of energy in a system is always the same. Energy is never lost and energy is never created.

Sometimes it is difficult to track where the energy goes. For example, most of the kinetic energy when you clap your hands is transferred to air as sound, but you might also notice that your hands get warm. This demonstrates that some of the original energy is transformed to heat.

In a game of pool, the white cue ball is struck, providing it with kinetic energy. The kinetic energy of the white ball is then *transferred* to the coloured ball.



Electrical energy supplied to the light globe is *transformed* into heat and light energy in the thin filament in the centre of the globe. The light energy is the desirable energy, but the heat is considered 'wasted' energy because it has no benefit to us.



INVESTIGATION 11.1

Popping corn

AIM: To investigate the transformation of energy

You will need:

saucepan with lid
vegetable oil
popping corn
Bunsen burner
matches
heatproof mat

- Pour a little cooking oil in the saucepan.
- Pour enough popping corn into the saucepan to cover the base and place the lid securely on top.
- Light the Bunsen burner and heat the saucepan in a blue flame, making sure the flame is spread evenly over the base of the saucepan.
- Heat the corn until the popping stops.
- Turn off the Bunsen burner, put the saucepan on the heatproof mat to cool and take the lid off the saucepan to observe any changes.
- Record your observations.

Discussion

1. What type of energy did the popping corn have before heating? What type did it have during heating?
2. Even though you could not see the corn when the lid was on, how do you know that an energy transformation took place?

INVESTIGATION 11.2

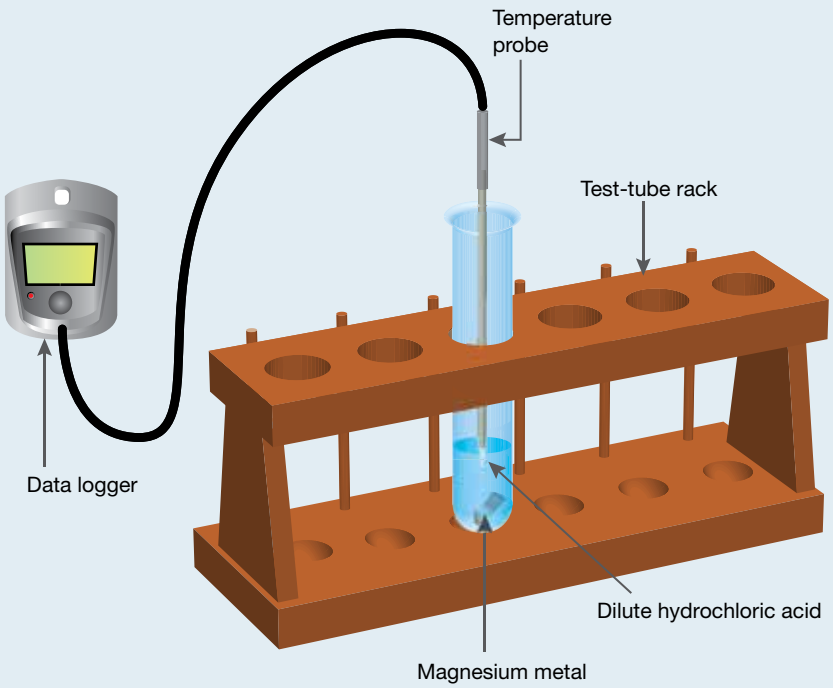
Energy and chemical reactions

AIM: To investigate the energy changes in exothermic and endothermic reactions

Chemical reactions often involve energy changes. Chemical reactions that get hot because they generate heat are called **exothermic** reactions. Chemical reactions that cause the reactants to drop in temperature absorb heat from the environment and are called **endothermic** reactions.

You will need:

dilute (0.1M) hydrochloric acid solution
test tubes
test-tube rack
data logger and temperature probe (or glass thermometer accurate to 0.2 °C)
1 cm long strip of magnesium metal
ammonium chloride
spatula



Reaction 1

- Pour approximately 2 mL of dilute hydrochloric acid solution into a test tube in a test-tube rack.
- Place the temperature probe or thermometer into the solution and record the initial temperature once it reaches a steady value.
- Put the strip of magnesium metal into the acid solution and record your observations. Swirl the contents of the test tube and record the maximum temperature reached.

Reaction 2

- Pour 2 mL of tap water into a clean test tube.
- Place the temperature probe into the solution and record the initial temperature once it reaches a steady value.
- Quickly remove the temperature probe and add half a spatula of ammonium chloride.
- Replace the temperature probe in the test tube and record your observations. Swirl the contents of the test tube and record the minimum temperature reached.
- Record all your observations and measurements in a single suitable table.

Discussion

1. Which reaction was exothermic and which was endothermic? How do you know?
2. Identify the energy transformation that took place in the exothermic reaction.
3. Explain why the temperature drops in an endothermic reaction.

INVESTIGATION 11.3

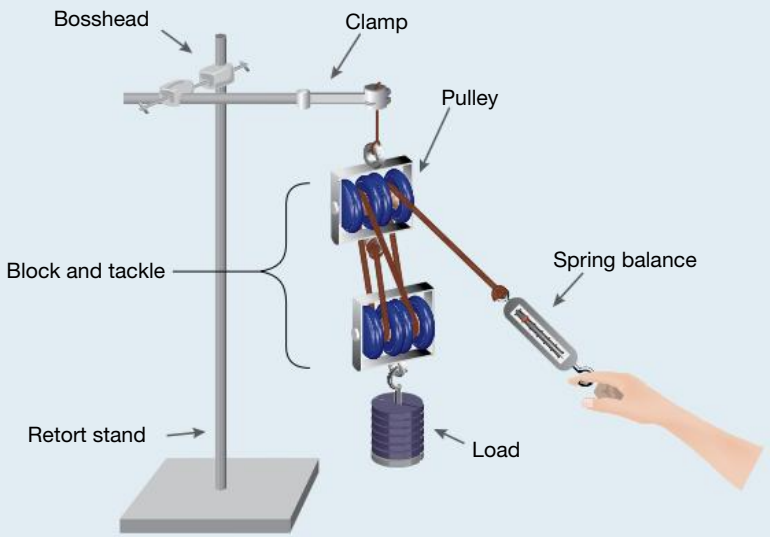
Investigating energy use with a block and tackle

AIM: To compare the energy required to lift a weight using a block and tackle with that required to lift it by hand

A block and tackle is a system of pulleys that allows heavy loads to be lifted with minimal effort. In this experiment you will compare the energy use with and without the use of a block and tackle for lifting heavy loads.

You will need:

500 g or 1 kg load
5 N or 10 N spring balance
string
retort stand, bosshead and clamp
scissors
ruler
2 double pulleys



- Attach the load to the spring balance and record the force needed to lift the mass by hand.
- Calculate the work done (in joules) to lift the mass 0.1 m (10 cm) by hand using the formula:
  work = force × distance (in metres)
- Construct a block and tackle as shown at right.
- Attach the spring balance to the end of the string and record the force needed to lift the mass using the block and tackle.
- Calculate the work done in joules to lift the mass 0.1 m (10 cm) with the block and tackle using the above formula.
- Draw up a suitable table to record the force, distance and work done with and without the block and tackle. Be sure to use appropriate units for each measurement.

Discussion

1. Compare the work done to lift the mass using a block and tackle with that used when lifting the mass by hand. If there was a difference suggest why.
2. Compare the force required to lift the mass with the block and tackle with that required when lifting the mass by hand. What advantages does a block and tackle have in lifting loads?
3. If 50 J of work is done to lift a student up by 10 cm, use your results to estimate how much work would be needed using a block and tackle.

11.1 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.

Remember

1. **Recall** four types of energy.
2. **Identify** the type of energy:
   (a) a person has when running
   (b) a spring has when it is stretched.
3. Use a suitable example to **describe** what is meant by an:
   (a) energy transfer
   (b) energy transformation.
4. **Outline** the Law of Conservation of Energy.
5. **Identify** the different types of energy involved in a trampoline jump.

Think

6. Imagine riding your bike along a flat gravel road. If you brake suddenly, the bike eventually stops. It no longer has kinetic energy. However, the energy is not lost. **Describe** what happens to the kinetic energy.
7. A saucepan of water is heated to boiling on an electric hotplate. For this situation, list three examples of the ways that energy is transformed or transferred.

Calculate

8. **Calculate** the gravitational potential energy of a 2 kg cat sitting on a tree branch 15 metres from the ground.
9. **Calculate** the kinetic energy of a 60 kg sprinter running 8 m/s.
10. A child sitting at the top of a playground slide has 2000 joules of gravitational potential energy. She flies off the end of the slide with 1200 joules of kinetic energy.
    (a) **Calculate** the amount of energy transformed to types of energy other than kinetic energy.
    (b) Suggest what these other energy types might be.

Create

11. Construct a poster to **outline** the different energy types that are involved in the operation of an appliance such as a hair dryer. Add labels to your poster showing where the different types of energy are used or produced.
12. Use the **Coaster** interactivity in the Resources tab to identify the positions on a roller-coaster ride where the car has more kinetic energy and where it has more gravitational energy.

learnON RESOURCES — ONLINE ONLY

- **Complete this digital doc:** Worksheet 11.1: Types of energy (doc-12436)
- **Complete this digital doc:** Worksheet 11.2: Gravitational potential energy (doc-12437)
- **Complete this digital doc:** Worksheet 11.3: Converting gravitational potential energy to kinetic energy (doc-12438)
- **Complete this digital doc:** Worksheet 11.4: Endothermic and exothermic reactions (doc-12439)
- **Try out this interactivity:** Coaster (int-0226)
- **Watch this eLesson:** Energy in disguise (eles-0063)

11.3 Heat and temperature

11.3.1 Heat

Heat is a form of energy and, like other forms of energy, it can be measured in joules (J). Heat and **temperature** are not quite the same thing. The temperature of a substance is a measure of how hot or cold it is. It is usually measured in degrees Celsius (°C) using a **thermometer**.

In many cases, substances with more heat energy have a higher temperature, but this may not always be the case. For example, on a cold day, a gas heater may provide a small bedroom with 1000 J of energy and increase the room's temperature to 26 °C. The same gas heater may provide a large living room with 1000 J of energy

but increase the room's temperature to only 23 °C. Both areas have the same amount of heat energy, but the bedroom has a higher temperature because the energy is heating a smaller volume of air.

Why temperature changes

Heat energy flows from a hotter object to a colder one. When an object receives heat energy, its particles move faster and its temperature rises. When an object loses heat energy to another object, its particles move more slowly and its temperature drops.

11.3.2 The flow of heat

Heat continues to flow from hotter objects to colder objects until their temperatures are equal. The movement of heat then stops. Heat never flows from colder to hotter objects.

For example, if a cup of hot chocolate is left sitting on a bench, it cools down. The fast-moving particles in the hot chocolate lose some of their energy to the air near the cup. The hot chocolate keeps cooling until it reaches room temperature. If chilled juice is left sitting on a bench, it warms up. The particles in the juice gain some energy from the warmer air around the glass. If left out of the fridge, the juice warms up until it reaches room temperature.

11.3.3 Thermometers

When an object absorbs heat, its particles move faster. The faster the particles move, the more space they take up. As the particles take up more and more space, the object expands.

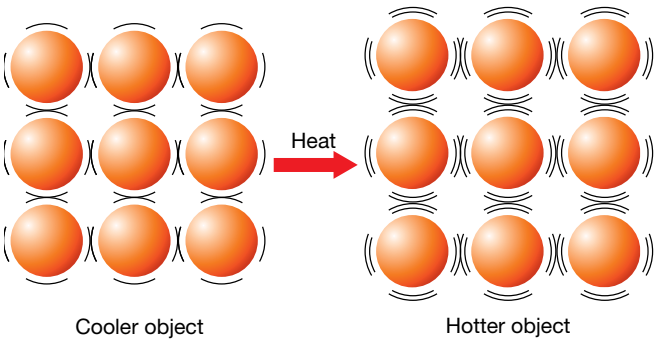
A thermometer works because the substance inside it takes up more space when it is heated. The substance used in most modern thermometers is alcohol, dyed red to make it easier to see.

Most glass thermometers measure temperatures to ±1 °C but digital thermometers are more accurate and can often measure temperatures to ±0.1 °C. Digital thermometers are commonly

A digital thermometer used to check a patient's temperature

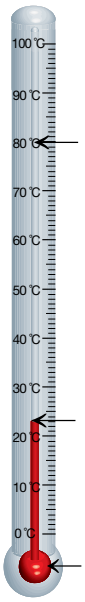


The temperature of an object or substance depends on how fast the particles inside it are moving. The faster the particles move, the higher the temperature.



During cold weather, snakes lie against warm rocks that have absorbed some heat from the sun. The fast-moving particles in the rocks transfer some of their energy to the snake, warming it up.





Column
A very fine column rises from the bulb, up the thermometer. When the bulb is heated, the alcohol inside heats up too. As the alcohol expands, it has only one place to go — up the column! The amount that the alcohol expands depends on its temperature. Higher temperatures make the alcohol expand further up the column.

Scale
The scale is designed so that the height of the alcohol in the column indicates the temperature. This thermometer would be useful for measuring temperatures between 0 and 100 °C. It is measuring a temperature of 23 °C.

Bulb
The dyed alcohol is stored in the bulb of a thermometer.

used by doctors to check whether a patient has a high temperature. You might use a digital thermometer in your experiments if you need to measure small temperature changes with great accuracy.

11.3.4 How heat is transferred

Heat moves from a region of high temperature to a region of low 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 in liquids and gases. Radiation can occur through any space, even in a vacuum.

Heat transfer by conduction

The metals used to make pots and pans are very good **conductors** of heat. This helps to ensure that the heat from the flame or hotplate is spread evenly.

Heat travels by conduction when fast-moving particles collide with other particles nearby, making them move faster. Heat can travel by **conduction** through objects, or from one object to another, such as from a cooktop to a saucepan.

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 that they are made of are far apart. Solids are usually very good conductors of heat because the particles in them are packed closely together, although not all solids conduct heat well. Metals are generally good conductors of heat and electricity while non-metals, such as glass, plastic and wood, do not conduct as well. Materials that conduct heat and electricity poorly are called **insulators**.

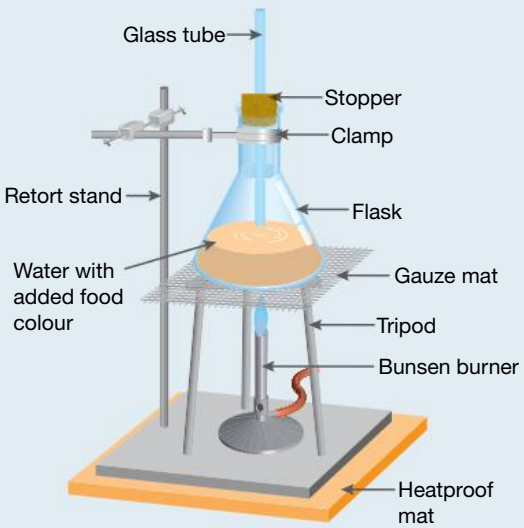
INVESTIGATION 11.4

Modelling a thermometer

AIM: To model a thermometer using the expansion and contraction of a liquid

You will need:

heatproof mat, Bunsen burner and matches
gauze mat and tripod
rubber stopper containing a glass tube
retort stand
bosshead and clamp
food colouring
water-based marker



- Set up the equipment as shown in the diagram.
- Use the retort stand and clamp to keep the flask and glass tube steady.
- Use a water-based marker to mark the level of coloured water in the glass tube.
- Light the Bunsen burner.
- Observe what happens to the level of coloured water in the glass tube while it is being heated. Record your observations.
- Turn the Bunsen burner off before the water spills out of the tube.
- Observe what happens as the water cools. Record your observations.

Discussion

1. Explain how the equipment used in this experiment could be used as a thermometer.
2. Use the particle model to explain what happens to the level of water when the flask is heated and cooled.

INVESTIGATION 11.5

Comparing rates of conduction

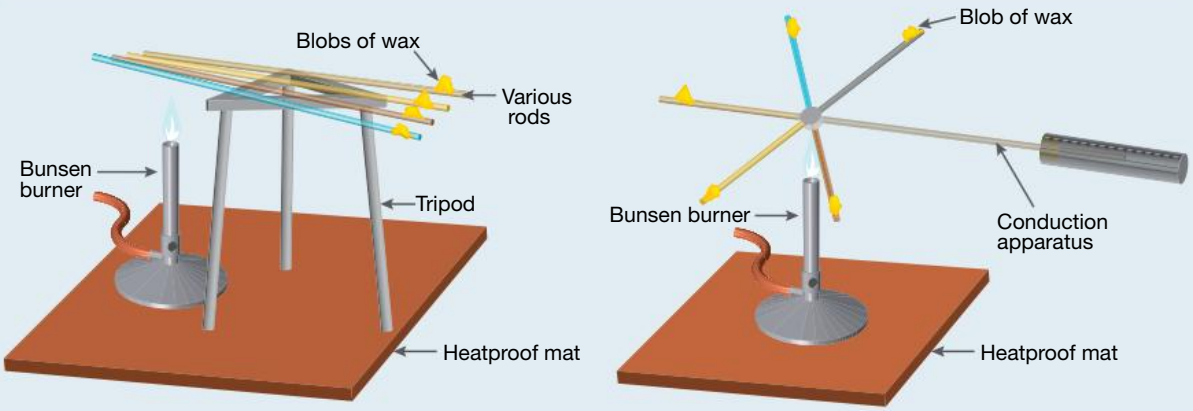
AIM: To compare the rates of conduction through different materials

You will need:

heatproof mat	*variety of rods (such as copper, iron, brass, glass) or a conduction apparatus*
Bunsen burner	*wax candle*
matches	*ruler*
tripod	*stopwatch*

- Set up the equipment using either the tripod and rods (as shown below left) or the conduction apparatus (as shown below).

Two ways to conduct this experiment



- Light the candle and melt a blob of wax onto each rod at the same distance from the end of each.
- Light the Bunsen burner, turn it to the blue flame and start the stopwatch as you begin to heat the end of each rod.
- Draw up a suitable table to record the time it takes each blob of wax to melt and produce drops of wax. Stop heating after 5 minutes.
- Draw an appropriate graph to present your findings.

Discussion

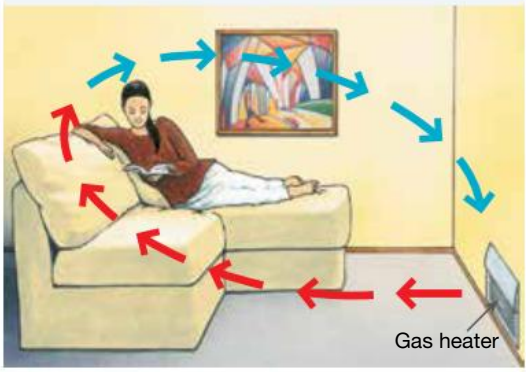
1. What evidence is there to suggest that heat travelled along the rods?
2. Through which rod did heat travel the fastest?
3. Which rod is the poorest conductor of heat? What evidence do you have for this conclusion?
4. Why was it important to put the blobs of wax the same distance from the Bunsen burner?

11.3.5 Heat transfer by convection

Have you ever noticed that, in summer, the air in a two-storey house is warmer upstairs than downstairs? You may have heard the saying that 'hot air rises'. On the previous page, you learned that heat travels by conduction fastest in solids because the particles are more closely packed together. The transfer of heat by conduction in liquids and gases is not very efficient; instead, heat travels through liquids and gases by **convection**.

Convection heaters work on this mode of heat transfer. The heater blows out warm air, which then rises. As the warm air rises, it transfers some of its energy to the surroundings causing the air to cool and so begin 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.

Convection currents consist of warm air rising and cool air falling.



INVESTIGATION 11.6

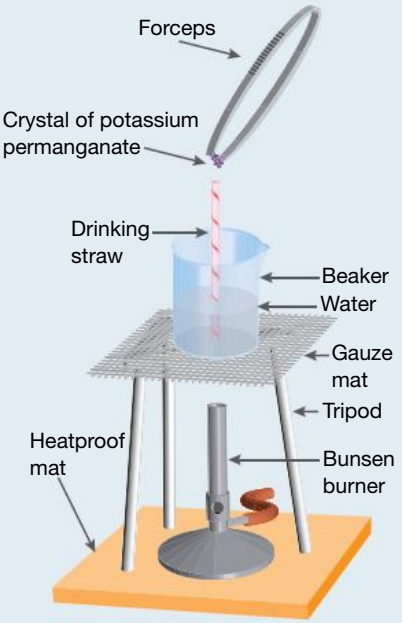
Modelling convection currents

AIM: To observe the transfer of heat in a liquid by the process of convection

You will need:

250 mL beaker
heatproof mat, Bunsen burner and matches
tripod and gauze mat
potassium permanganate crystal
drinking straw
forceps

- Fill the beaker with water. Place it over the Bunsen burner as shown at right.
- Carefully drop a crystal of potassium permanganate down the straw.
- Slowly remove the straw, making sure not to disturb the water.
- Light the Bunsen burner and turn it to a blue flame, being careful not to disturb the beaker.
- Draw a diagram to show what happens as the water is heated and the crystal begins to dissolve.



Discussion

1. Explain why the chemical moved the way it did in this experiment as it dissolved.
2. This investigation modelled heat transfer by convection. Outline the benefits of modelling concepts in science.
3. Are convection currents modelled accurately in this investigation? What limitations are there to modelling this concept?

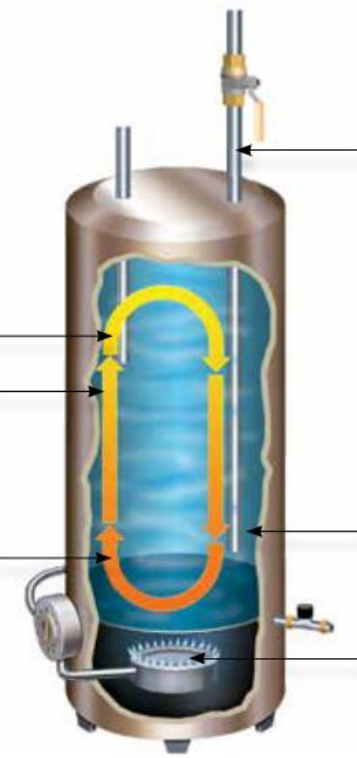
11.3.6 Convection currents within a hot-water tank

A hot-water tank has a heating element in the base that creates a convection current. This current causes the warm water to circulate in the water tank ready for delivery to the hot-water tap.

Ready to use
A pipe connects the water at the top of the water tank with the shower and every other hot-water tap. If this water is not used, it cools and sinks to the bottom, where it is heated again.

Rising
Hot water rises because its particles are further apart than those in cold water; it is less dense than cold water. As the hot water rises, cold water continues to move to the bottom of the water tank.

Heating
The flame heats the cold water at the bottom of the tank. The particles move more quickly and spread out.



Cold water in
Cold water enters the hot-water system through a pipe that takes it to the bottom of the tank.

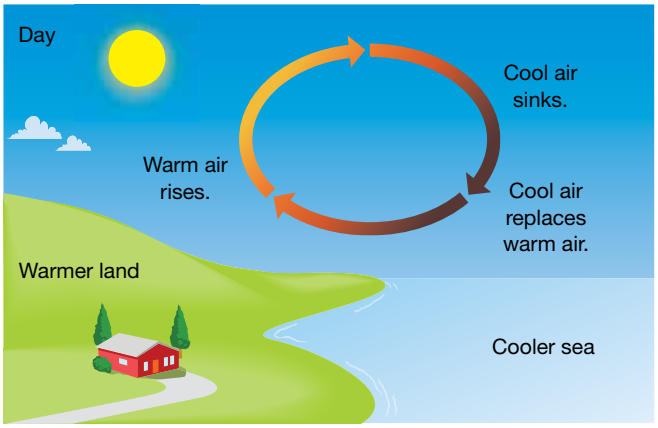
Sinking
The particles in the cold water move more slowly than the particles in the warmer water. The cold water sinks because its particles are close together. Cold water is more dense than hot water.

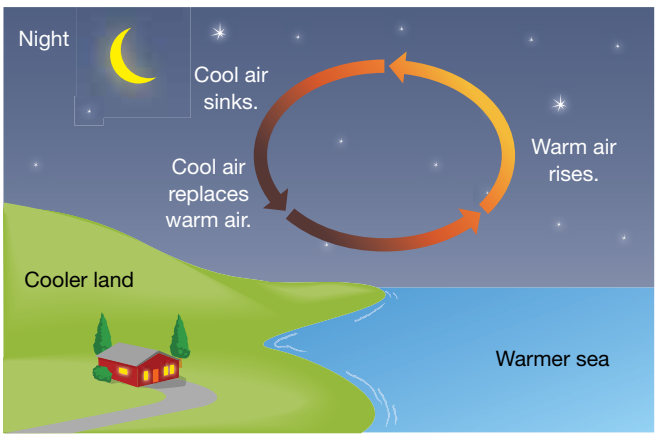
Gas flame
A gas hot-water system has a flame at the bottom of the water tank. The flame heats the water near the bottom of the tank. An electric hot-water system has elements inside the water tank, similar to those in a kettle.

11.3.7 Coastal sea breezes

Sea breezes are often created by convection currents along a coastline. As land along the coast warms up during the day, warm air rises. This warm air cools as it rises above the sea. Cool air then moves in to replace the warm air over the land causing a circular convection current. At night, the sea temperature is higher than the temperature on land so convection currents move in the opposite direction.

Sea breezes caused by convection currents





11.3.8 Heat transfer by radiation

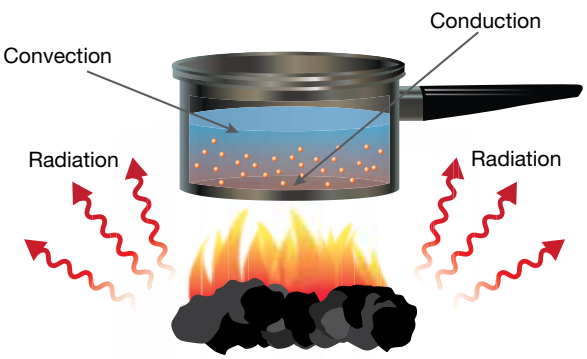
The sun provides energy to the Earth. Without heat from the sun, the Earth would be far too cold for humans to live on. Heat from the sun must travel through space to reach the Earth. The heat does not travel by conduction or convection because there are too few particles in space to transfer the energy between the sun and the Earth. Instead, heat from the sun reaches the Earth by **radiation**.

Heat that travels by radiation is called **radiant heat**. Radiant heat travels very quickly because it does not rely on the movement of particles to move energy from one place to another. The heat from the sun takes only about eight minutes to reach the Earth.

Place your hand near the base of the globe of a lamp. Turn on the lamp. You should feel the heat from the globe almost instantly. Heat does not travel through air easily by conduction. Rather, the heat reaches your hand by radiation.

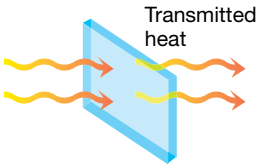


A camp cookout — heat is transferred by radiation, conduction and convection.

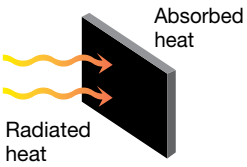


11.3.9 Transmission, absorption and reflection

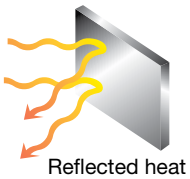
Radiant heat behaves in a similar way to light. When radiant heat strikes a surface, it can be **reflected**, **transmitted** or **absorbed**. Most surfaces do all three; some surfaces are better reflectors, others are better absorbers and some transmit more heat.



Transmitted radiant heat
Clear objects, like glass, allow light and radiant heat to pass through them. The temperature of these objects does not increase quickly when heat reaches them by radiation.



Absorbed radiant heat
Dark-coloured objects tend to absorb light and radiant heat. Their temperatures increase quickly when heat reaches them by radiation.



Reflected radiant heat
Shiny or light-coloured surfaces tend to reflect light and radiant heat away. The temperature of these objects does not change quickly when heat reaches them by radiation.

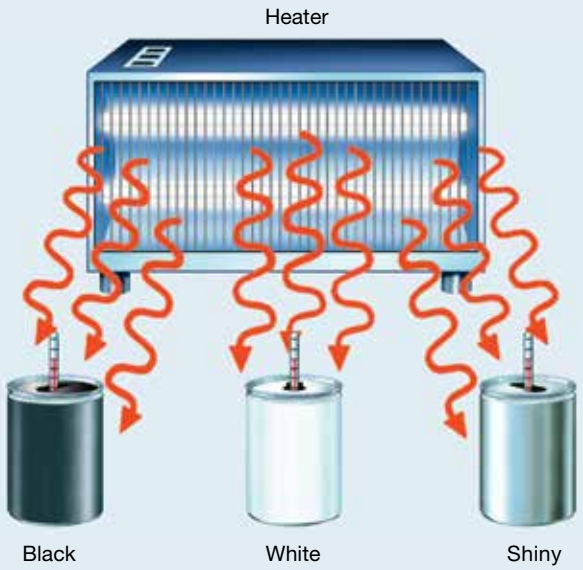
INVESTIGATION 11.7

Absorbing radiant heat

AIM: To investigate the effects of different surfaces on the absorption of radiant heat

You will need:

heater or microscope lamp
3 identical soft-drink cans
black and white paint
3 thermometers (or 3 temperature probes and a data logger).



- Paint one can white and one black, and leave the third with an unpainted, shiny surface.
- Pour equal amounts of cold tap water into each can.
- Place the thermometers in the cans.
- Measure the initial temperature of the water in each can. Record your results in a suitable table.
- Place the three cans at the same distance from the radiator or lamp. Turn on the power to the heat source.
- In a suitable table, record the temperature of the water in each can every 2 minutes for a total of 14 minutes.

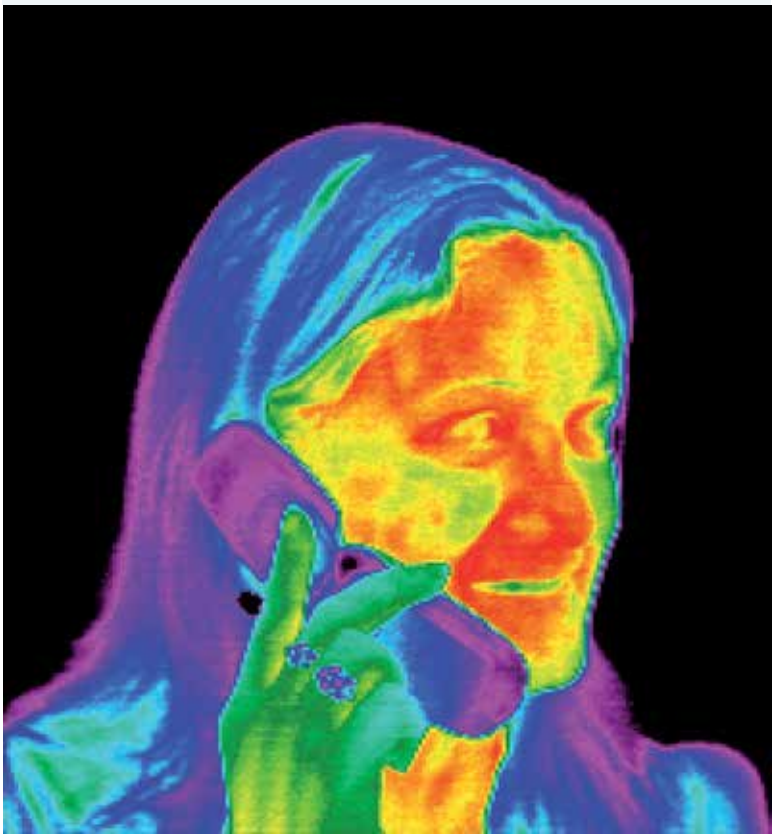
Discussion

1. Why was the temperature of the water measured before starting to heat the water?
2. How did the temperature of the water in each can change during the experiment?
3. Which cans were better absorbers and which were better reflectors of radiant heat? How can you tell?
4. Why was it important to use cans that were the same size?

11.3.10 Detecting heat using infra-red scanners

All objects, including the human body, radiate some heat. The human body usually radiates more heat than the environment around it. Infra-red scanners detect the radiant heat coming from the human body. That's why infra-red scanners are useful for finding people lost at sea, in bushland or even buried under a collapsed building.

An infra-red image. Hotter areas of the body appear red on the scan while colder areas are blue.

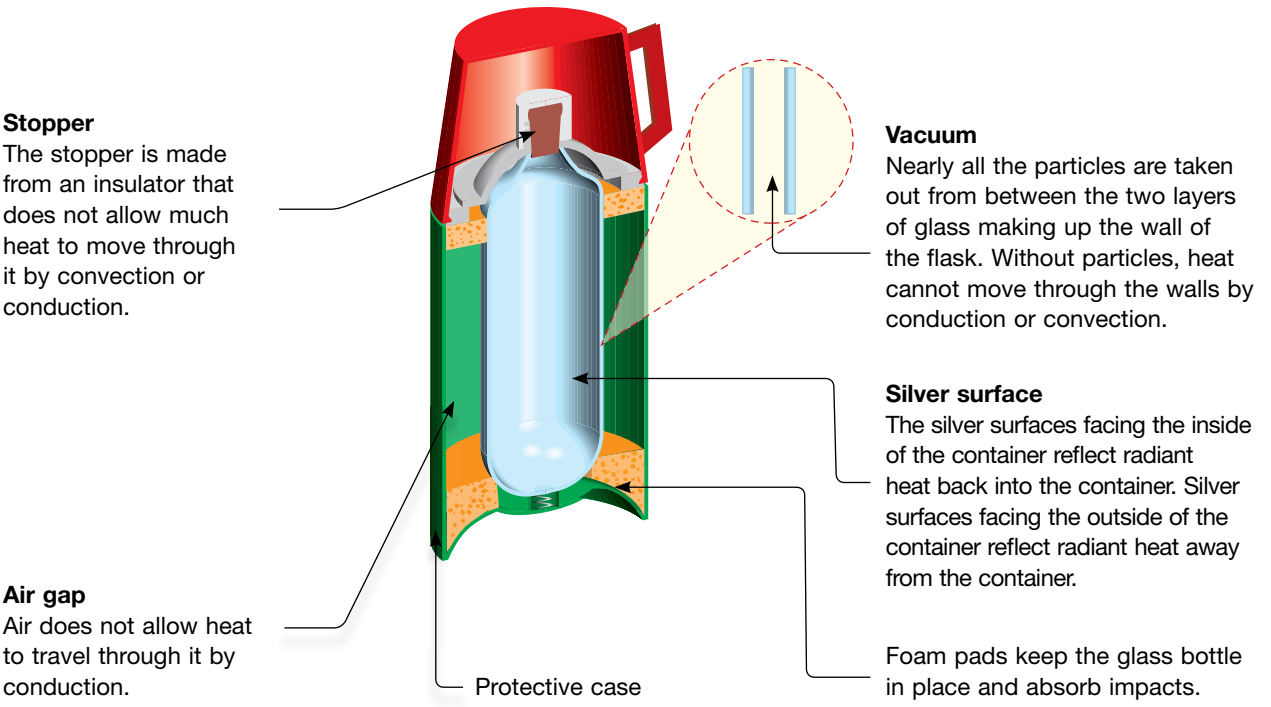


11.3.11 Insulation

Slowing down the flow of heat is the key to keeping drinks cool in the summer and warm in the winter. On a hot day, heat flows from the hot environment to a cold drink, until they are both at the same temperature. On a cold day, heat flows from a warm drink to the cooler environment, until their temperatures are equal.

Heat does not travel into or out of a thermos flask very easily. For this reason, a thermos flask can be used to keep cold drinks cold and warm drinks warm. A thermos flask has a number of features that slow heat transfer by conduction, convection and radiation.

A thermos flask



11.3.12 Insulating your body

The temperature of the human body is about 37 °C. When the air temperature is much less than this, heat moves from your body to the environment. In very hot weather, heat moves from the environment to your body.

Unless your body is touching a very hot or a very cold object, you won't gain or lose heat by conduction very easily. Most of the movement of heat near your body happens by convection and by radiation.

Clothes keep you warm in winter by stopping your body heat from escaping.

Fabrics made from **natural fibres**, like wool, are good insulators of heat. This is because natural fibres contain only very small pockets of air. This prevents convection currents forming and carrying heat away.

Air can flow easily through thin material, keeping you cool in summer. Loose fitting clothes allow more convection currents to form. The convection currents help heat to escape from your body.



1 Absorbing radiant heat
When sunlight strikes any object, including the human body, the object absorbs some radiant heat.

2 Losing radiant heat
All objects give off some radiant heat. The amount depends on the temperature around the object. On a hot day, an object does not transfer as much radiant heat away as in the cold weather.

3 Convection
Convection currents form when the heat from your body warms the air next to it. The air rises, taking some of your body heat away with it. Convection currents can form only in air that is free to move.

HOW ABOUT THAT!

We do most of our cooking using energy from electricity and gas or wood fires. However, these are generated from non-renewable resources: that is, resources that we use much faster than we can replace them. Scientists have been working to harness renewable energy, such as solar energy, for everyday tasks. The solar cooker project has been particularly important in developing countries that rely on wood fires for cooking. Solar cookers work by transforming light energy from the sun into heat energy. The inside of the concave-shaped cooker is covered in a shiny metal such as aluminium. Light rays from the sun are reflected off the shiny surface and concentrated into a central area called the focus. Food placed at the focus cooks more quickly because the light (and, hence, heat) is more intense at this point.



INVESTIGATION 11.8

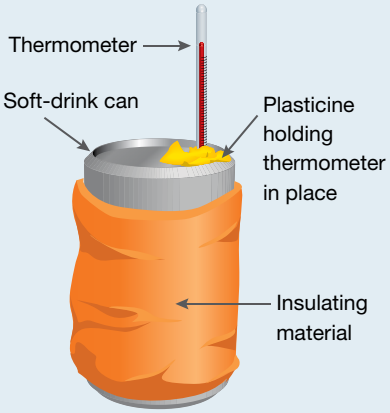
Reducing heat loss

AIM: To investigate the effectiveness of a variety of insulating materials

You will need:

4 identical soft-drink cans
range of insulating materials (such as wool, nylon, cotton, plastic padding and newspaper)
plasticine
data logger and temperature probes or thermometers

- Design an experiment to compare how well various insulating materials retain the heat in a can filled with hot water.
- Outline the procedure used in your experiment. Include a can filled with water and without insulation as a control in your experiment.
- A thermometer can be held in place in each can with plasticine.
- Tabulate your results; plot your data and draw a curve of best fit for each material on a single set of axes.



Discussion

1. Identify the variables that you attempted to control in this experiment.
2. Explain whether it was important for each can of water to start off at the same temperature.
3. Which material was the best insulator? Support your conclusion with your data.
4. The insulating material slowed the transfer of heat by two processes. Name these processes and explain how the insulation prevented them.
5. Why was it important to include a control in this experiment?

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** which state of matter (solid, liquid or gas) allows heat to travel fastest by conduction.
2. **Outline** the effect of heating an object on the speed of the particles inside it.
3. **Explain** how a thermometer works.
4. **Explain** the difference between heat and temperature.
5. **Identify** which method of heat transfer does not require a medium containing particles.
6. When radiant heat strikes a surface, there are three different possible outcomes. **Identify** each.
7. **Outline** two uses of infra-red scanners.

Think

8. Cars of which colours are most likely to require airconditioning in hot weather? **Explain**.
9. **Explain** whether heat can travel by conduction through a vacuum (where there are no particles).
10. **Identify** some of the materials commonly used for saucepan handles. **Explain** why these materials have been used for this purpose.
11. **Explain** why the smoke from a factory does not keep rising forever.
12. Use a diagram and refer to convection currents to **explain** why coastal Sydney often experiences a sea breeze in the afternoon.
13. **Explain** why it is almost impossible for criminals to hide from infra-red scanners.
14. **Identify** two features of a thermos flask that reduce heat loss by:
    (a) conduction
    (b) convection.
15. **Outline** two ways that heat moves between your body and the environment.
16. **Explain** what is wrong with the following statement. ‘A thick coat keeps the cold out.’

Interpret

17. The table below shows results collected during an experiment similar to the one on page 423.

Material	Time taken for piece of wax to melt (s)
Rock	8.0
Copper	6.5
Brick	11.0
Silver	5.0
Aluminium	7.7

List the items in the table from the best conductor of heat to the poorest conductor of heat.

Investigate

18. **Investigate** what a convection oven is and how it works.
19. **Investigate** the contribution of James Joule to science.
20. The change in temperature of water inside shiny, black and white containers was investigated in on page 426. Design and carry out an experiment to investigate the heat-absorbing properties of different colours. Which colours absorb more heat? How can you tell?

learnon RESOURCES — ONLINE ONLY

Complete this digital doc: Worksheet 11.5: Conduction and convection (doc-1244)

11.4 Using electrical energy

11.4.1 Moving electricity

At the flick of a switch, you can turn on a light, use a computer or play a song on your smartphone. In these devices, **electrical energy** is converted to light, sound or other useful form of energy.

Pulling off a jumper made of synthetic material often creates static electricity. Static electricity results when positive or negative charge builds up in a non-conducting material, which does not allow electrons to move through it.

The electricity that flows out of a power outlet or battery is not static but can travel through a conducting path called an **electric circuit**. Just as electrons are transferred when static electricity is created, electrons are also the charges that travel through electric circuits. Interestingly, electrons were not discovered until the 1900s, well after electricity had been discovered. Therefore, it was originally thought that positive charges travelled through electric circuits.

The electrical energy supplied by a battery or power outlet provides the charges (electrons) in an electric circuit with the ability to do work: that is, to move around the circuit and power a light globe or an appliance. Hence, electrical energy is an example of potential energy.

When you switch on a light, turn on a computer or press 'Call' on a mobile phone, you are creating a continuous path for electrons to travel; the circuit is said to be closed. Electrons continue moving through a circuit until the power supply is removed or the switch is turned off, which opens the circuit, creating an incomplete path.

11.4.2 An electrical circuit

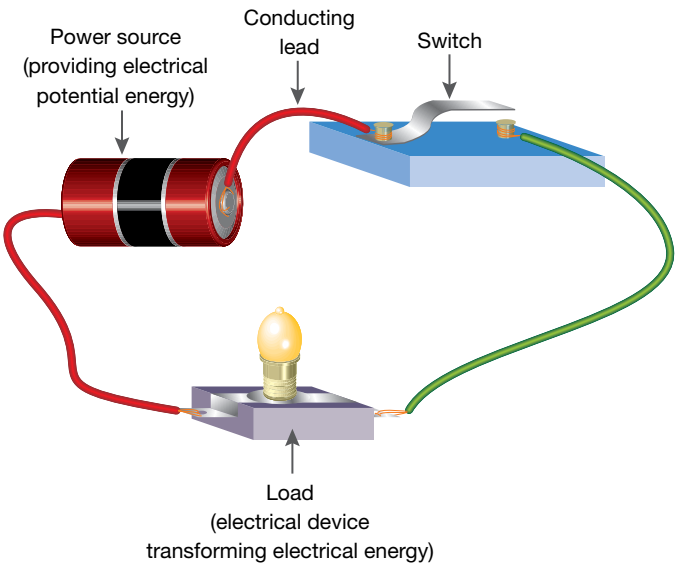
For an electric circuit to do its job of converting electrical energy to other useful forms of energy, three things are necessary:

- a **power supply**, to provide electrical charges in the circuit with electrical potential energy. In most household appliances the power supply is provided by batteries or by connecting to a power outlet.
- a **load**, which is an electrical device such as a light globe, in which electrical energy is transformed into other forms of energy
- a **conducting path** so that electric charge can flow around the circuit. Connecting leads (wires) provide this path.

Listening to music on a smartphone converts electrical energy to sound energy.



The essential elements of an electric circuit



INVESTIGATION 11.9

Making the right connections

AIM: To investigate how to create an electric circuit

Try this investigation at the start of this unit.

You will need:

two 1.5 V batteries
two 3 V globes
3 wire leads
Blu-tack

Activity 1

- Using the equipment provided, how would you connect a battery to a single light globe so that it glows? Try it out until you've got it working.
- Record your successful set-up as a labelled diagram.

Discussion

1. What did you try that didn't work?
2. Where does the electrical energy come from?
3. In which direction do you think the electric charges flow? Label this on your diagram.

Activity 2

- How would you connect two batteries to a single light globe? Try it out until you've got it working.
- Record your successful set-up as a labelled diagram.

Discussion

4. What effect does providing a second battery have on the light? Explain why.

Activity 3

- How would you connect two light globes to a single battery so that you get a:
  (a) bright glow
  (b) dim glow?
- Record your successful set-up as a labelled diagram.

Discussion

5. Explain your results.

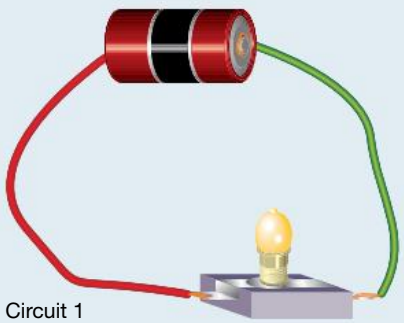
INVESTIGATION 11.10

Switched on circuits

AIM: To investigate the effect of the position of the switch in an electric circuit

You will need:

3-volt globe and holder
1.5-volt battery
5 connecting leads with alligator clips or banana plugs
2 tapping switches



Circuit 1

Part A

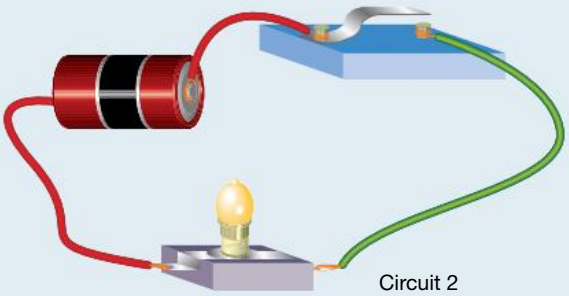
- Connect circuit 1 as shown.

Discussion

1. How can you stop the globe in circuit 1 from glowing? Explain why.

Part B

- Connect circuit 2 as shown.
- Close the switch.
- Open the switch and remove the globe from its holder. Close the switch.



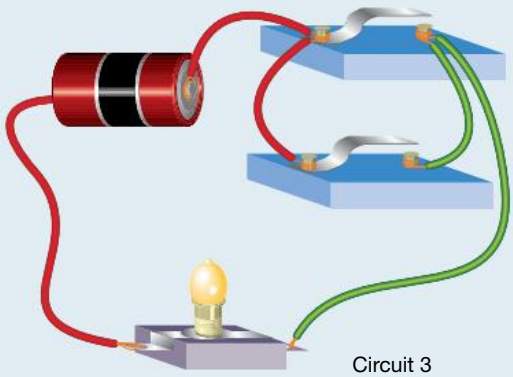
Circuit 2

Discussion

2. Describe what happens to the globe in circuit 2 when the switch is closed.
3. Does the globe light up when it is removed? Why not?

Part C

- Put the globe back in its holder and add a second switch as shown in circuit 3.



Circuit 3

Discussion

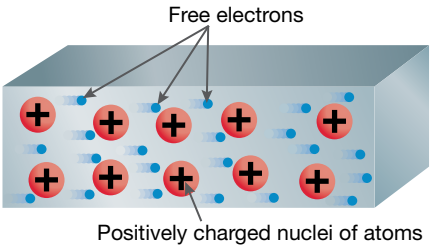
4. Explain what happens to the light globe in circuit 3 when:
   (a) neither of the switches is closed
   (b) either one of the switches is closed
   (c) both of the switches are closed.
5. How could a circuit like this be useful in the wiring at your home?

11.4.3 Current and voltage — what's the difference?

As we now know, electrons are the carriers of electric charge around a circuit. The rate of flow of electric charge through an electric circuit is called the **electric current**. The greater the current, the more electric charge passes a given point in the circuit per second. The unit of electric current is the **ampere**, which is commonly abbreviated to amps (A).

The **voltage** of the battery or power supply is a measure of how much electrical potential energy is available to push the charges through the circuit. If the circuit is not closed, current cannot flow and the electrical energy cannot be used to move the charges around. The unit of voltage is the **volt** (V).

Electrons in conductors are free to move.



11.4.4 Conductors and insulators

The cords that plug into power points from electrical appliances are coated in plastic. Electricity can pass through the metal wires inside the cord because metal is an electrical conductor. It cannot pass through the plastic because it acts as an electrical insulator. Without the plastic, electricity could pass through to any person touching the cord.

Metals and non-metals

Most metal objects are conductors of electricity because some electrons in the atoms of metals are free to move. When metal wires are connected to a power supply, free electrons in the wires move through the wires to create an electric current.

Insulators do not allow electrons to flow through them. Many objects made from non-metals are insulators. The electrons inside insulators are strongly bound to the nuclei of the atoms and cannot move easily.

Transporting electricity

To get to our homes, electricity travels through metal cables. The cables are usually high above the ground out of reach.

It is important for the electricity to travel along the cables, but not through the poles that support the cables. For this reason, power poles are often made of wood or concrete. Both of these materials are insulators.

These towers are made of conducting materials, but the cables are insulated from them with glass or porcelain discs. These larger towers are used to transport electricity at very high voltages, usually between places that are far apart.



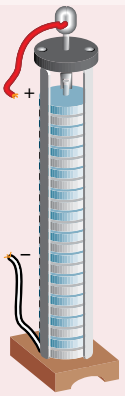
HOW ABOUT THAT!

The volt and the ampere, the units of voltage and electric current respectively, were named after two men who made important discoveries about electricity more than 50 years before Thomas Edison invented the electric light globe.

Alessandro Volta (1745–1827), an Italian physicist, invented the first electric battery in 1800. Volta discovered that a moist cloth placed between two different metals could produce a small electric current. The first electric battery is known as the voltaic pile and consists of alternating disks of copper and zinc. Each pair of copper and zinc discs was separated by a piece of cloth soaked in salty water. Volta's early battery was about 30 cm high.

André Ampére (1775–1836) was a French mathematician with an interest in physics and chemistry. According to some historians, he had mastered all known mathematics by the age of 12. He is best known for his discovery that two nearby parallel wires carrying electric current could attract or repel each other.

Volta's pile — the first battery



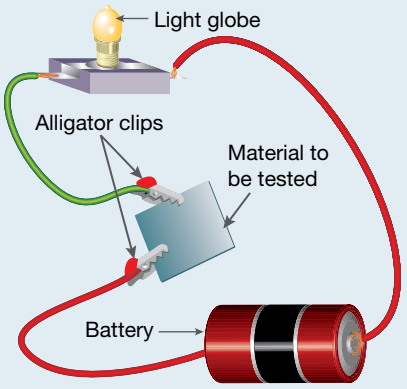
INVESTIGATION 11.11

Conductors and insulators

AIM: To test whether materials are conductors or insulators

You will need:

light globe and light-globe holder
battery or other power supply (no more than 6 V)
3 connecting wires (at least 2 with alligator clips)
objects to test (for example, copper sheet, paper, plastic, coin, fabric, iron nail, glass, ice-cream stick, paperclip and aluminium foil)



- Set up the equipment as shown at right.
- Draw up a table like the one below.

Object	Light globe on or off?	Conductor or insulator?

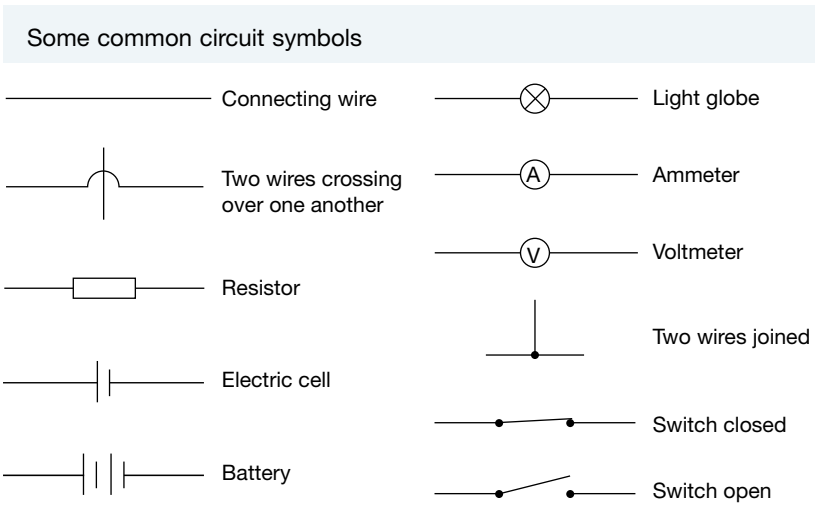
- Place each item in turn between the alligator clips.
- Complete the table for each item as you test it.

Discussion

1. List the items that conducted electricity.
2. What is the purpose of the light globe?
3. Look at the items that are conductors of electricity. What do they have in common?
4. (a) Is air a conductor of electricity?
   (b) How can you test to see if it is?
5. Are the alligator clips conductors or insulators? Explain your answer.

11.4.5 Circuit diagrams: a common language

Circuit diagrams are used to communicate the type of electric components included in a circuit and how those components are arranged in the circuit. In circuit diagrams, internationally accepted symbols are used to represent each circuit component. Straight lines are used to represent the wire leads connecting the components.



11.4.6 Electricity at work

A light in the dark

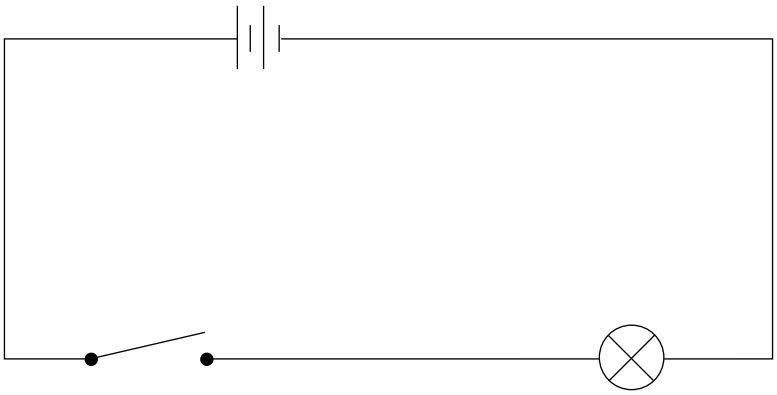
Many battery-operated devices such as torches use more than one battery connected end to end as shown in the diagram on the next page. It is important to ensure that the positive end of one battery is connected to the negative end of the other. When two 1.5-volt batteries are connected end to end, the total voltage supplied to the circuit is 3.0 volts. This means that twice the electrical energy is available to move the electric charges around the circuit.

The load in a torch circuit is the globe. When the switch is closed, electric current flows around the circuit. As electric charge passes through the globe, its electrical energy is transformed to heat in the filament.

The filament inside the globe is made of tungsten metal, which glows brightly when it gets hot, producing lots of light.

The conducting path in a torch consists of the spring that pushes the battery up against the base of the globe and the metal strip, which includes the switch. When the switch is open, the metal strip does not make contact with the globe and the circuit is not complete.

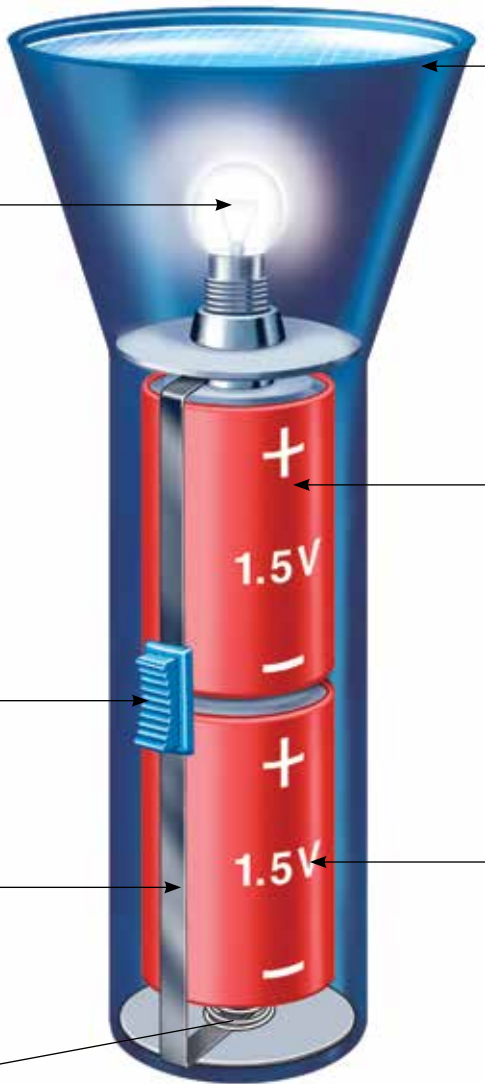
Circuit diagram for a torch



11.4.7 Series circuits

In a torch circuit, the batteries, globe and switch are connected one after the other. Conductors, including the metal strip, link the components. The circuit is a single, complete loop. This type of circuit is called a **series circuit**.

A torch is a simple electric circuit.



Filament
This small coil of wire in a globe is called a filament. When a current passes through a globe, the filament gets hot and produces light. The electrical energy from the batteries is converted into light and heat energy in the filament.

Switch
When the switch is open, the metal strip does not make contact with the base of the globe. A current cannot flow. When the switch is closed, the metal strip is forced against the base of the globe to complete the circuit. The electric current then flows.

Metal strip
The metal strip completes the circuit between the batteries and the globe.

Spring
The spring keeps the batteries in contact with the base of the globe.

Plastic covering
The plastic cover is an insulator and so doesn't allow a current to flow through it.

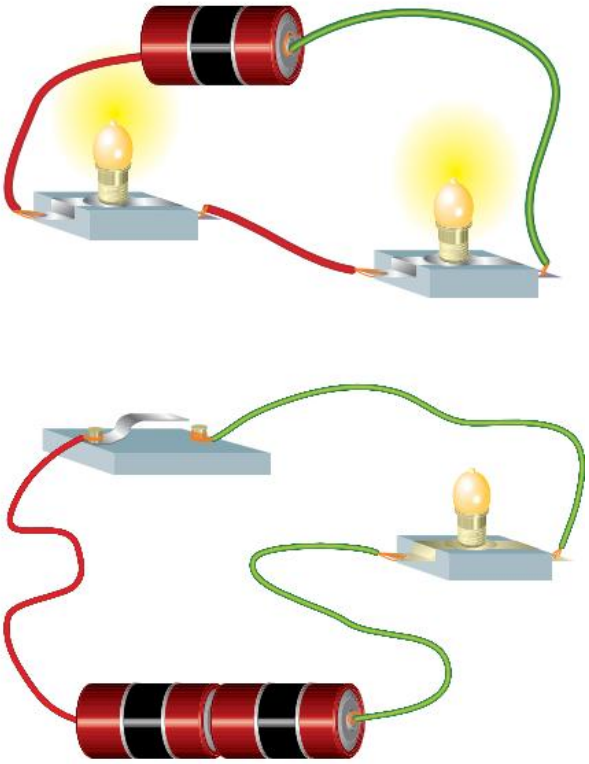
Globe base
The globe base is connected to the metal strip and the batteries.

Batteries
Batteries provide electrical potential energy for the torch to work. The energy stored in each battery forces electrons to move from the negative terminal through the circuit and towards its positive terminal at the other end. This can happen only if the battery is part of a closed circuit.

Voltage
These batteries supply 1.5 volts (V) each. Together, the two batteries provide 3 V to the torch. The voltage is a measure of how much energy the battery supplies the electrons to move them around the circuit. Notice how they are connected end to end, with the positive terminal of one battery against the negative terminal of the next.

The good thing about series circuits is that they are simple to put together; however, if any part of a series circuit does not work, such as one of the globes in the first circuit above right, none of the circuit will work. A series circuit does not work if even one part of it breaks down.

Both of these circuits are series circuits. The components in these circuits are connected one after another.



When batteries are connected in series, electrons flowing through the circuit must flow through each battery. The electrons are provided with electrical energy from each battery.

Note that the positive terminal of one battery is joined to the negative terminal of the other.

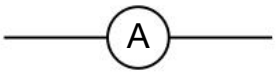


11.4.8 The ammeter

An **ammeter** is a device that measures electric current, which is the rate of charge flow through a circuit. The more electrons that flow through the circuit per second, the higher the current and the higher the ammeter reading.

An ammeter is always connected in series. This way, the electrons that flow through the circuit will also flow through the ammeter.

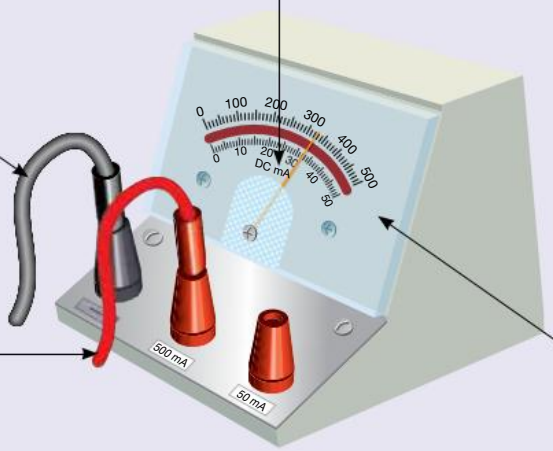
The circuit symbol for an ammeter is shown here.



The negative (black) terminal of the ammeter is connected so that it is closer to the negative terminal of the battery or power source than to the positive terminal.

This ammeter measures milliamperes.

The positive (red) terminal of the ammeter is connected closer to the positive terminal of the battery or power source. Select the positive terminal with the highest maximum current value first. If the current is too small to register on this scale, switch to the more sensitive (smaller maximum current) terminal.



There are usually two or more scales on an ammeter. Your selection of positive terminals tells you which scale to read.

CAUTION: An ammeter is easily damaged. If the current reading goes off the scale, switch off the circuit immediately.

11.4.9 Parallel circuits

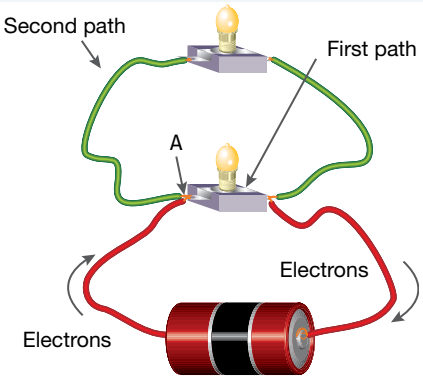
Imagine what would happen if the electrical appliances in your home were all connected in series? Every time a light blows out, no other electrical appliance would work.

To avoid this problem, most circuits contain components connected parallel. This means that each component is connected in a separate parallel path. A **parallel circuit** works even when one part of it breaks down.

A power supply, commonly called a 'power pack', converts the 240 volts supplied by a power outlet to a maximum of 12 volts, a safer voltage to use in class investigations. Power packs are more environmentally friendly in class experiments than batteries, which are consumables and so contribute to landfill. Most experiments require you to use DC or direct current, which is supplied by the red and black terminals of the power pack. The power overload light indicates that the current through a circuit is too high, usually because the load in the circuit is inadequate. In this situation, a circuit breaker built into the power pack is triggered, thus opening the circuit and preventing damage.

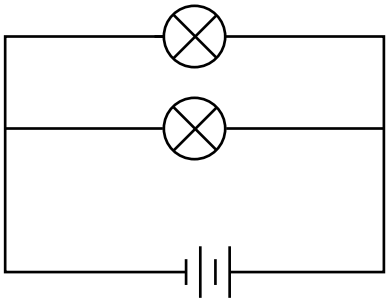


A parallel circuit has more than one path for the electricity to follow. If one of the paths has a break in it, the other paths will still work. Only components in the broken part of the circuit will stop working.



At point A, the electrons can move along either the first path or the second path. If the paths are identical, half of the electrons will take the first path and the other half will take the second path. Although the electric current is divided between the two paths, electrons in each path will have the total voltage (electrical energy) provided by the battery.

A **circuit diagram** of a parallel circuit



Christmas lights — if these lights are connected in parallel, when one light blows, the others still work.

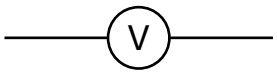


11.4.10 The voltmeter

The energy provided to electrons as they move around a circuit is supplied by a battery or other power source. As the electrons move around the circuit, some of their electrical energy is transformed into other forms of energy by the components in the circuit, which act as a load. The electrical energy that is transformed by components along the circuit is measured in volts using a **voltmeter**.

Like an ammeter, a voltmeter is placed in a circuit with its positive terminal closer to the positive terminal of the power supply than the negative terminal. But, unlike an ammeter, a voltmeter is connected parallel to a component in a circuit.

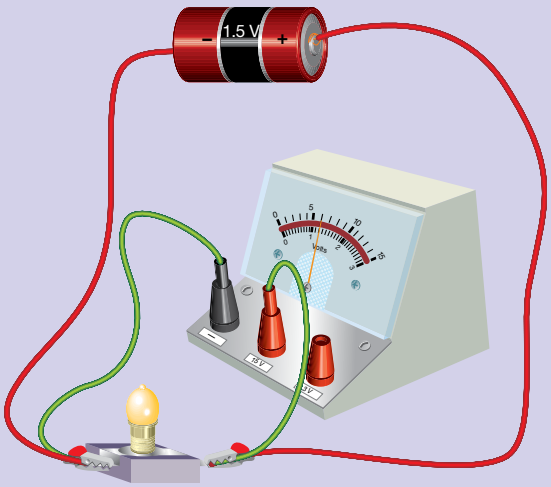
The symbol for a voltmeter is shown below.



The voltmeter in this circuit tells us how much of the electron's energy is converted into light and heat energy. As it is the only component in the circuit, this light globe uses almost all of the energy provided to the electrons.

This battery provides 1.5 V of energy to the electrons as they leave the battery.

Voltmeters can measure how much energy is transformed as electrons pass through a component.



INVESTIGATION 11.12

Series and parallel

AIM: To compare the brightness of globes in series and parallel circuits

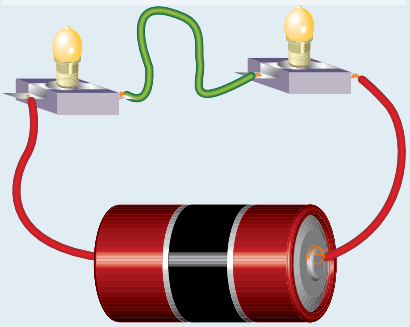
You will need:

two 3-volt globes and holders
1.5-volt battery and holder
6 wire leads

Part A: Series circuits

- Connect one globe and the battery together with wire leads so that the globe lights up.
- Add a second globe in series with the first globe as shown in the diagram at right.
- Remove one globe from its holder.
- Replace the globe that was removed, and then remove the other one.

Globes connected in series



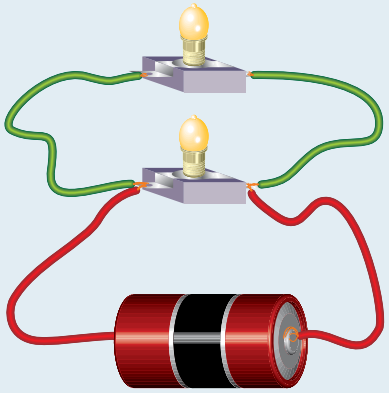
Discussion

1. Draw a circuit diagram to represent the circuit that you have connected.
2. How does the brightness of the two globes compare with the brightness of a single globe connected to the same battery?
3. What effect does the removal of one globe have on the other globe when the battery is connected?
4. Does it matter which globe is removed?
5. Can electric current flow in this series circuit when either globe is removed? Explain.
6. Would it be sensible to have all of the ceiling lights in your home connected in series? Give a reason for your answer.
7. What would be the effect on the other globes if a third globe were added in series? If a third globe is available, test your prediction.

Part B: Parallel circuits

- Connect the two globes, battery and wire leads as shown in the diagram at right.
- Remove one globe from its holder.
- Replace the globe that was removed, and then remove the other one.

Globes connected in parallel



Discussion

8. How does the brightness of the two globes compare with the brightness of a single globe connected to the same battery?
9. What effect does the removal of one globe have on the other globe?
10. Does it matter which globe is removed?
11. Can electric current flow in this parallel circuit when either globe is removed?
12. Outline whether the removal of one globe has any effect on the other globe.
13. What would be the effect on the other globes if a third globe were added in parallel? If a third globe and enough connecting leads are available, design a circuit to test your prediction.

11.4.11 What affects brightness?

The brightness of each globe depends on both the voltage supplied and the electric current. In series circuits, the electrons share the total energy (voltage) supplied among all of the globes in the circuit. The more globes there are, the more the energy needs to be shared and the less brightly they glow.

The branches of a parallel circuit do not share the energy supplied to the circuit. So, identical globes placed in parallel glow with equal brightness. No matter how many branches are added to a parallel circuit, the brightness of each identical globe is the same.

These lights are connected in parallel. Why?



What about in your home? All lights are connected parallel but, because they are not all identical, some may glow more brightly than others. This is because the electrons flowing through each light are supplied with the same voltage, but the electric current flowing through the lights in each parallel branch may differ.

The numbers printed on light globes tell us how quickly the globes use energy. A 23-watt light globe uses energy more quickly than an 11-watt light globe and so it shines more brightly. The electrons that pass through these globes convert the same amount of energy (240 V in Australia), but a greater current passes through the 23-watt globe than the 11-watt globe in any given time. So, current, as well as voltage, affects brightness.

11.4.12 Batteries: portable converters of chemical energy

The electrical energy needed to operate most electrical devices in the home and at school is obtained by plugging into a power outlet. In NSW, much of this electrical energy is generated by coal-fired power stations where the chemical energy in this fossil fuel is converted to electrical energy, which is then transmitted along power lines throughout the State.

Batteries are portable providers of electrical energy. While there are many different types of batteries, they all convert chemical energy directly to electrical energy. When a device is connected to a battery, a chemical reaction occurs within the battery that produces electrical energy. This is known as an **electrochemical reaction**. Italian physicist Alessandro Volta first discovered this process in 1799.

A battery is made up of one or more cells connected in series. However, in everyday language, the term 'battery' is used for a single cell as well. An electric cell consists of a positively and a negatively charged metal strip, called **electrodes**, and a substance through which electric charge can flow. A **chemical reaction** takes place inside the cell, creating an electric current.

A variety of dry cell batteries

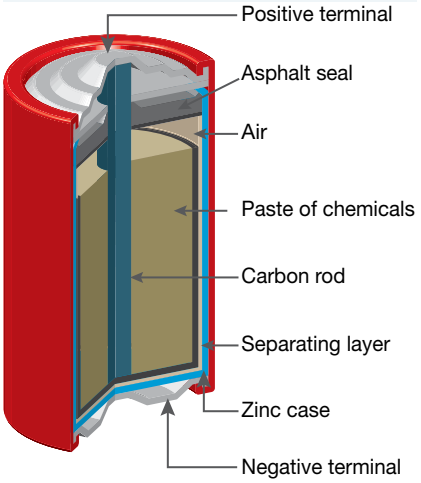


11.4.13 Dry cells

The general-purpose cells used in torches, calculators and toys are filled with a paste of chemicals. The two electrodes are:

- a central rod of carbon, which is connected to the positive terminal of the cell
- a zinc case, which is in contact with the negative terminal of the cell.

A general-purpose dry cell



When a conducting path is provided between the two terminals of the cell, a chemical reaction takes place between the paste and the zinc case. This releases electrons, allowing an electric current to flow around the circuit. A separating layer stops the chemicals from reacting while the cell is not in use.

These general-purpose cells are called **dry cells** because the **electrolyte**, the substance inside the cell through which electric charge moves, is not a liquid.

Other types of dry cells work in the same way but use different electrodes or electrolytes.

Alkaline cells contain an electrolyte that allows a greater electric current to flow. They are ideal for heavy-duty torches, battery-operated shavers, mp3 players and digital cameras.

Mercury cells produce a voltage that is much steadier than other dry cells. Their steady output makes them ideal for pagers, hearing aids, watches, calculators and measuring instruments.

11.4.14 9- and 12-volt batteries

Many of the cells that you use provide 1.5 V of energy to the electrons in a circuit. When you purchase a 9 V battery, it is actually six 1.5 V cells connected in series and packaged together.

Car engines use 12 V batteries. Like other batteries, the chemical reaction in these batteries creates free electrons. One difference between car batteries and other batteries is that a car battery recharges when the car engine is running. The running engine reverses the chemical reaction in a battery. After a few years, the battery needs to be replaced because some of the products of the chemical reactions inside the battery build up, stopping it from recharging properly.

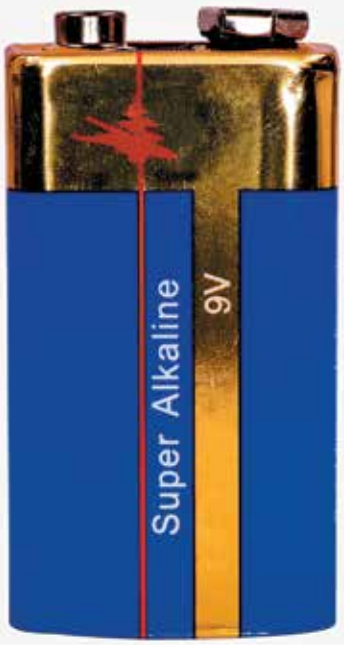
Powering your laptop and mobile phone

Lithium-ion batteries are a technological advancement on the dry cell. They provide around 3.6 volts, more than twice that of a standard AA alkaline battery and yet they are compact and rechargeable. Hence, they are commonly used in laptops and mobile phones.

In a lithium-ion battery, one electrode consists of a lithium compound and the other is most commonly graphite (a form of carbon). These batteries are named for the lithium ions, which are charged lithium atoms, that travel through the electrolyte material.

Lithium-ion batteries can be recharged by running the chemical reaction between the electrodes in the reverse direction. Typically this is done by a charger that is plugged into a power outlet. The ability to be recharged many times over without much loss of chemical energy is another major advantage of the lithium-ion battery. Lithium-ion batteries can handle hundreds of charge/discharge cycles.

Six 1.5 V cells are connected in a 9 V battery.



A typical lithium-ion battery and its charger



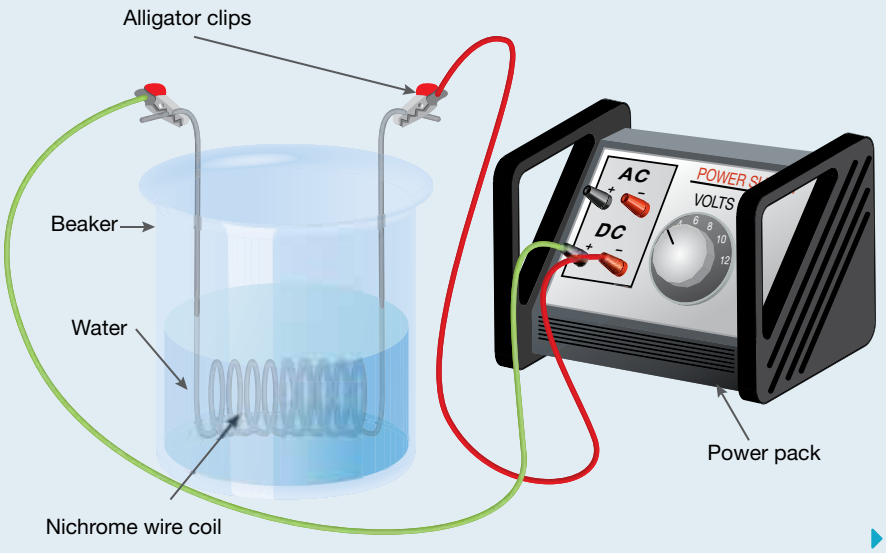
INVESTIGATION 11.13

Modelling an electric kettle

AIM: To model the transformation of electrical energy into heat energy in a kettle

You will need:

250 mL beaker
100 mL measuring cylinder
50 cm length of fine nichrome wire
pen or pencil
power pack
2 wire leads and alligator clips
thermometer (preferably digital) or a data logger and temperature probe
stopwatch



- Measure 100 mL of water into the 250 mL beaker.
- Wind the middle of the nichrome wire around a pen or pencil to make a coil from the wire.
- Connect the apparatus as illustrated on the previous page.
- Record the initial temperature of the water before the power is switched on.
- Set the power pack to 2 V, turn it on and start the stopwatch.
- Measure the temperature of the water every minute for 10 minutes.
- Record your data in a table like the one below.
- Draw a line graph to illustrate the temperature change.

Time (min)	0	1	2	3	4	5	6	7	8	9	10
Temperature (°C)											

Discussion

1. Describe the temperature change that you have observed.
2. Describe the energy transfer that is taking place.
3. Extrapolate your graph to predict the temperature after 15 minutes.
4. Predict the temperature change you would observe if 4 V was supplied to the coil.

INVESTIGATION 11.14

A lemon battery

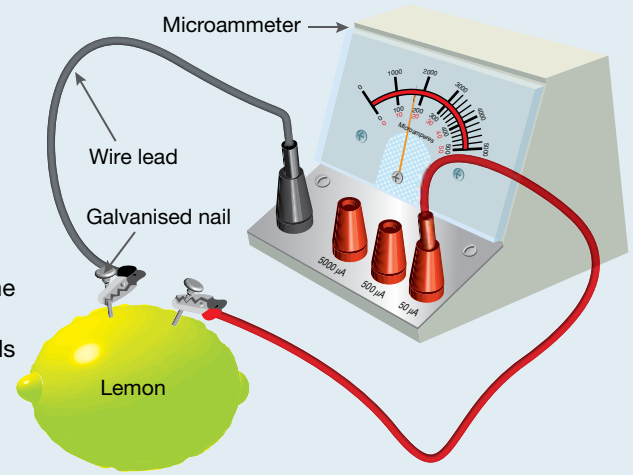
AIM: To investigate the electric current produced using citrus fruits

In this investigation, citrus fruits are used to create electrochemical cells, similar to the first cells developed using copper and zinc discs and salty water.

You will need:

3 lemons
range of nails (galvanised, iron, steel)
6 wire leads with alligator clips
microammeter

- Citrus fruits such as lemons can be used to make an electric cell. A chemical reaction occurs between the different metals and the acid in the fruit so that electrons are forced to move around a circuit.
- Squeeze each of the whole lemons to break up some of the pulp inside.
- Trial different arrangements of the lemons and metals to create the maximum possible current.
- Draw the arrangement that produced the maximum current, and record the current.



Discussion

1. What variables did you test to maximise the electric current produced?
2. Which variables affected the electric current produced?
3. Outline the energy conversion that is taking place in this experiment.

11.4 Exercise: Remember and think

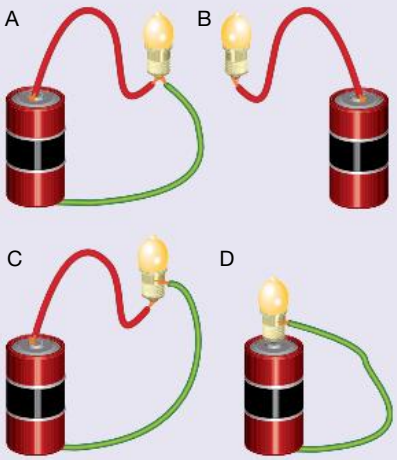
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

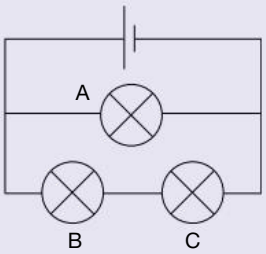
1. **Define** the term ‘closed circuit’.
2. **Identify** the part of an electric circuit in which electrical energy is changed into other useful forms of energy.
3. **Explain** why metals are better conductors of electricity than non-metals.
4. **Explain** why a 50-watt globe glows more brightly than a 25-watt globe.

Think

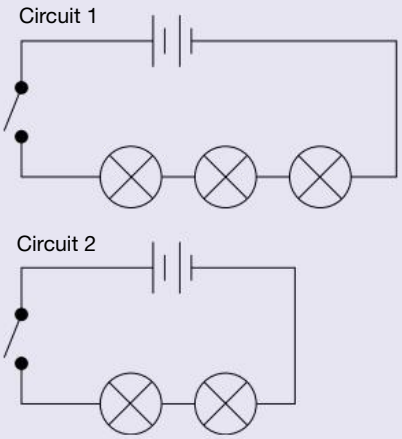
5. **Identify** what takes place inside a battery to cause an electric current to flow.
6. **Outline** why lithium-ion batteries are commonly used in laptops and mobile phones.
7. **Explain** why it is important to have circuit symbols that are recognised by scientists and electricians around the world.
8. **Identify** which of the following arrangements will allow the globe to light up.



9. A circuit is set up as illustrated at right.
   (a) If the filament of globe A breaks, do globes B and C remain lit or do they stop working also?
   (b) If the filament of globe B breaks, which globe or globes (if any) remain lit?
   (c) If the filament of globe C breaks, which globe or globes (if any) remain lit?



10. In a house, four light globes are connected parallel. However, the lights are in separate rooms. This means that a separate switch is needed for each globe. Draw a circuit diagram of this circuit.
11. Look at the two circuit diagrams at right. When the switches are closed in each circuit, the globes will glow.
    (a) In which circuit will the globes glow more brightly?
    (b) Explain your answer to part (a) in terms of the voltage available for each globe.



Apply

12. Draw a circuit diagram containing a battery, two globes in series and a switch.
13. Use symbols to draw a circuit diagram of the circuit used in part B of *Investigation 11.12* on page 439.

Create

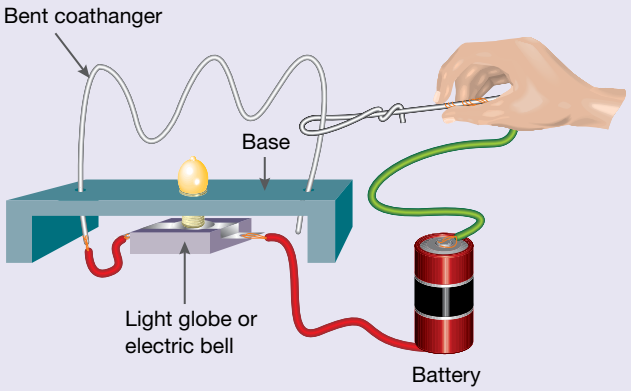
14. **Construct** a steady-hand tester (see the diagram on the next page). You will need a wire coathanger, a loop of thin wire, wire cutters, battery, electric bell or light globe, connecting wires, and a shirt box, shoe box or cereal packet for the base.

15. Design and create a circuit with two switches and an electric bell so that the bell rings when either one (or both) of the two switches is closed. Draw a picture and circuit diagram of your circuit. Invent your own symbol for the bell. If a bell is not available, use a light globe instead.

Investigate

16. Many battery manufacturers claim that their batteries are the best. Design an experiment to find out which brand of dry cell gives best value for money. Make sure your experiment is a fair one.

A steady-hand tester. The 'alarm' can be a bell hidden in the base or a globe attached to the base. Hide as much of the connecting wires as you can.



learnON RESOURCES — ONLINE ONLY

- **Complete this digital doc:** Worksheet 11.6: Simple circuits (doc-12441)
- **Complete this digital doc:** Worksheet 11.7: Series and parallel circuits (doc-12442)
- **Complete this digital doc:** Worksheet 11.8: Conductors and insulators (doc-12443)
- **Complete this digital doc:** Worksheet 11.9: Testing batteries (doc-12444)

11.5 Technological solutions to energy efficiency

Science as a human endeavour

11.5.1 Wasted energy

Energy transformations are common in most daily activities. As we walk along the ground, chemical energy in the food we eat is transformed into the kinetic energy of our motion as well as heat energy for our body through a process called metabolism. Jumping on a trampoline involves a continual conversion of elastic potential energy to gravitational potential energy and kinetic energy and back again.

The transformation of energy often has some unintended consequences. For example, electrical appliances transform electrical energy into other useful forms of energy, but some of the original electrical energy is converted to unwanted forms of energy because of limitations in the technology used to produce that appliance. The following table identifies examples of the energy conversions that take place in some common electrical appliances.

Device	Original form of energy	Original energy form converted to useful energy as …	Original energy form wasted by …
Microwave oven	Electrical	heat in the food	heating the air in the oven and the food container
Gas cooktop	Chemical	heat in the saucepan	heating the air, producing light and sound
Car engine	Chemical	kinetic energy of the car	heating due to friction between moving parts, and as sound
Incandescent light globe	Electrical	light	heating the globe and surrounding air

11.5.2 Energy efficiency

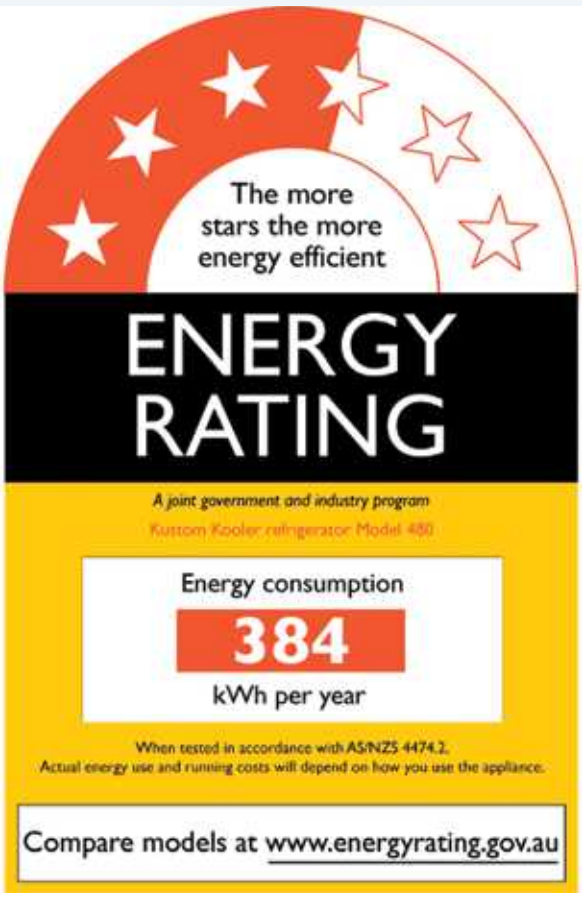
The efficiency of a light globe, cooktop or any other energy-converting device is a measure of its ability to provide useful energy. Efficiency is usually expressed as a percentage:

$$\text{Efficiency} = \frac{\text{useful energy output (J)}}{\text{total energy input (J)}} \times 100$$

Scientists and engineers are constantly developing more energy-efficient appliances. In Australia, the energy efficiency of an electrical appliance is indicated by an energy rating. Appliances with a 5-star rating consume the least electrical energy and minimise a consumer's electrical costs in running the appliance.

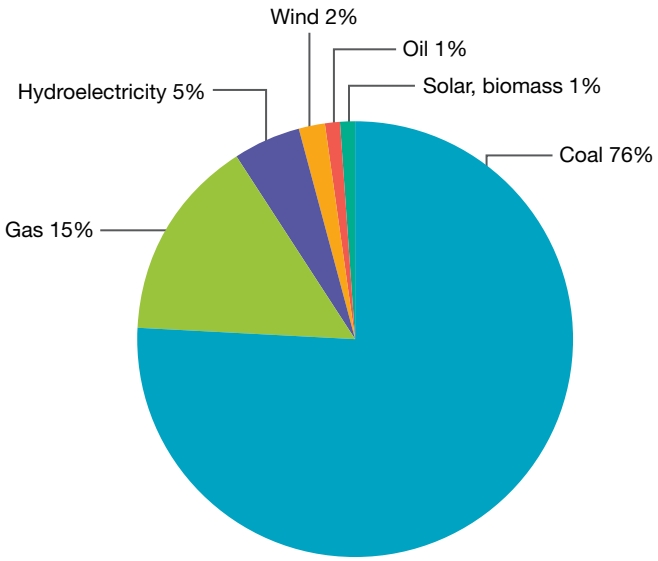
The energy efficiency of appliances is particularly important when considering that fossil fuels are commonly used in Australia to generate electricity and for heating and cooking.

The energy rating used for electrical appliances



Fossil fuels such as coal, gas and oil account for over 90 per cent of electricity generation in Australia.

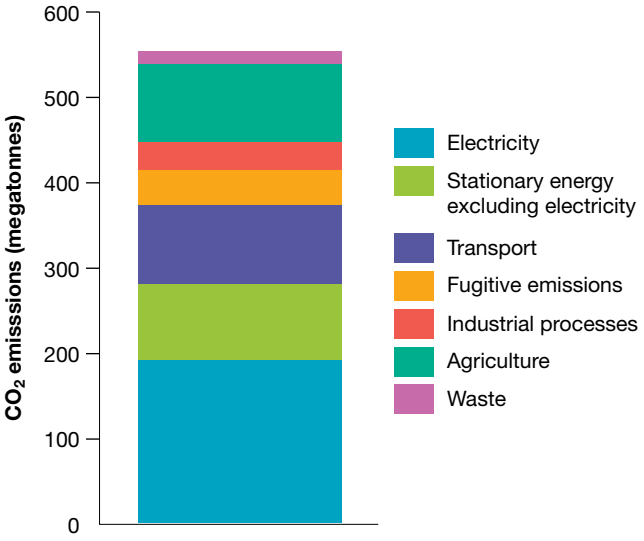
Energy sources for Australian electricity generation, 2008–09



Burning fossil fuels for electricity generation, heating and cooking releases greenhouse gases such as carbon dioxide. In fact, electricity generation by burning fossil fuels contributes 35 per cent of Australia's total greenhouse gas emissions, more than any other industry.

Minimising the use of fossil fuels reduces our greenhouse gas emissions and limits the impacts on climate change in the future. Advances in technology play a significant role in reducing our use of fossil fuels. These include the development of energy-efficient appliances and alternative energy sources for electricity generation such as solar, wind and tidal energy.

Carbon dioxide emitted by sector in 2011–2012 (millions of tonnes). Electricity generation is the biggest contributor of greenhouse gas emissions.



11.5.3 Advances in lighting

Lighting represents around 12 per cent of the electricity usage in households, and around 25 per cent of the electricity used by the commercial sector.

The light globes used for many years in Australian homes are called incandescent globes. Electricity in incandescent lights passes through a thin filament, generally made of tungsten metal, causing it to glow white hot. The light is a useful form of energy but the heat produced is a wasted form of energy. In incandescent globes, the tungsten slowly vaporises and builds up on the inside of the globe until the filament it is too thin to carry an electric current, and the globe burns out. Halogen globes, used in downlights, also work on the same principle but they are filled with a special gas that causes the vaporised tungsten to be deposited back onto the filament instead of the inside of the globe. Consequently, halogen globes last longer and also burn brighter than conventional incandescent globes, making them slightly more efficient.

(left to right) Light-emitting diodes (LED), an incandescent globe and a compact fluorescent lamp (CFL)



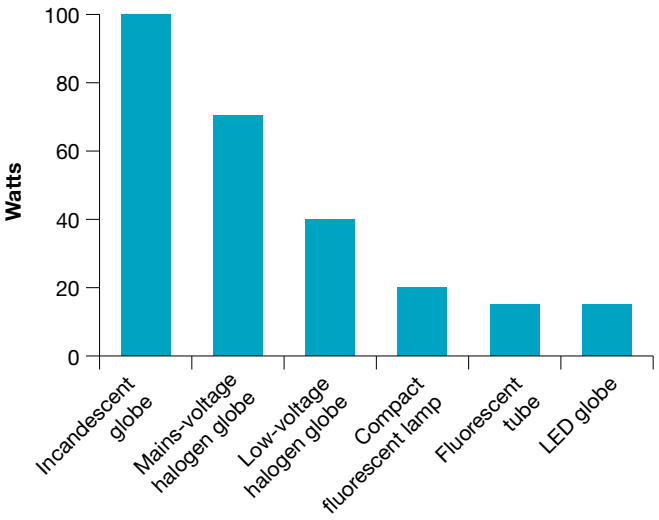
To encourage the use of more energy-efficient lighting, the Australian government has introduced minimum energy performance standards for lighting products. From 2010, incandescent light globes, which are less energy efficient, were phased out and replaced by more energy-efficient alternatives. Halogen globes, which are more efficient types of incandescent globes, continue to be available, but the traditional pear-shaped globes were phased out. More energy-efficient alternatives include compact fluorescent lamps (CFLs) and light-emitting diodes (LEDs), which use 20 per cent or less of the electricity required to produce the same amount of light as incandescent globes.

Any light globes with an efficiency less than 15 lumens per watt (lm/W) will no longer be available. Lumen (lm) is the unit used to measure light output, and watt (W) is a measure of electrical energy input per second.

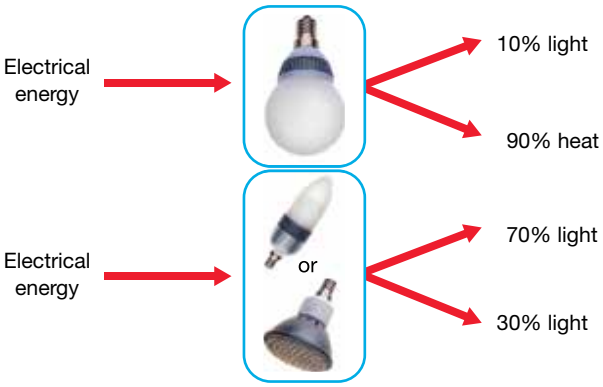
CFLs and LEDs are energy efficient because they minimise the amount of energy wasted as heat. Incandescent globes convert only 10 per cent of the supplied electrical energy to light, and the rest is released as heat; in CFLs and LEDs, this figure is closer to 70 per cent. The move to more efficient lighting is expected to reduce Australia's greenhouse gas emissions by 28 million tonnes between 2008 and 2020 by reducing the demand for electricity; this is equivalent to decommissioning a small coal-fired power station or taking

more than 500 000 cars off the road. It is expected to result in savings to the Australian economy of around $380 million per year by 2020, and net savings of more than $50 per year for each household that changes all of its incandescent light globes to compact fluorescent lamps.

Comparative amount of electrical energy used by different light globes to deliver the same light output as a 100-watt incandescent light globe



Compact fluorescent lamps and light-emitting diodes transform a greater proportion of electrical energy to light and less to wasted heat.



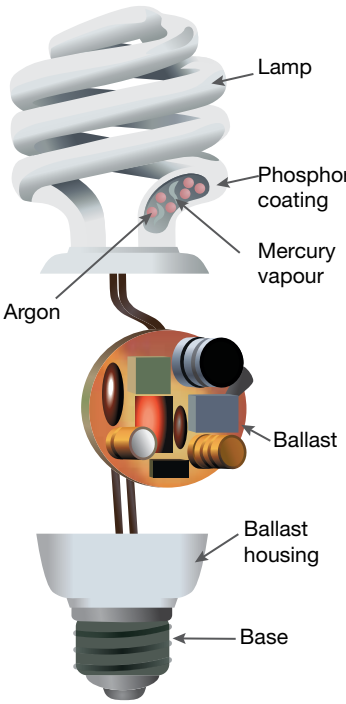
11.5.4 How do compact fluorescent lamps work?

A compact fluorescent lamp consists of a coiled glass tube. The tube is filled with argon gas and a small amount of mercury vapour. An electric current is passed through the gas-filled tube causing the mercury atoms to emit ultraviolet light. This excites a fluorescent phosphor coating on the inside of the tube, producing visible light. A compact fluorescent lamp's ballast regulates the current once the electricity starts flowing.

While compact fluorescent lamps represent a more energy-efficient alternative for lighting, they do contain very small amounts of mercury, a toxic chemical linked to the impairment of brain function. Due to their mercury content, CFLs should not be placed into glass recycling bins. Scientists and engineers are trying to reduce the mercury content of CFLs without sacrificing their energy efficiency. In fact, CFLs contained an average of 4 milligrams a few years ago; today they contain as little as 0.4 milligrams.

Interestingly, less mercury is released into the environment from the use of CFLs than incandescent light globes, even though CFLs contain mercury. This is because burning coal in power stations to produce electricity releases small amounts of mercury. CFLs use only about 20 per cent of the electricity that incandescent globes use to produce the same amount of light. This means that overall about 20 per cent of the coal needs to be burnt to produce the same amount of light, resulting in an overall reduction in mercury emissions of about 80 per cent.

The components of a compact fluorescent lamp



Even when the amount of mercury contained in a CFL is taken into account, the reduction in mercury emitted to the environment through power production means that the amount of mercury released over the life of a

CFL is significantly less than the amount that would be released by burning coal to power equivalent incandescent globes over the same period.

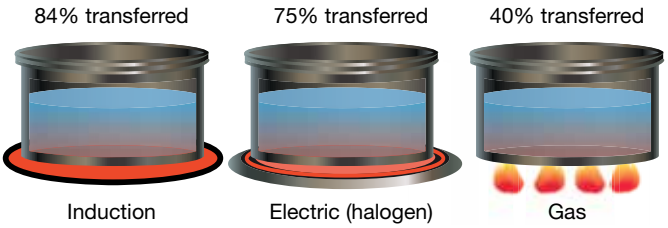
11.5.5 LED technology

Light-emitting diodes are miniature electrical components similar to those 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.

11.5.6 Advances in cooking

Along with developments in lighting, there have also been technological advances in energy-efficient cooking appliances. Traditional cooking uses a gas or electric hotplate. Induction cooking is a recently developed technology that transfers energy from the cooktop to the saucepan more efficiently than any other cooking appliance. In gas cooking, only 40 per cent of the heat supplied by the gas flame is transferred directly to heat the contents of a saucepan. The rest of the heat energy is wasted as light or heat to the surrounding air. Modern electric hotplates are more efficient with 70 per cent of the heat energy transferred to heat involved in cooking. Induction cooking, however, can achieve close to 85 per cent energy efficiency. Electricity supplied to metal coils within an induction cooktop creates an oscillating magnetic field that directly heats any saucepan placed on it, as long as it is made of a magnetic metal, such as stainless steel. With induction cooking, energy is supplied directly to the saucepan by the magnetic field; therefore, the cooktop itself does not get hot and so almost all of the source energy is transferred to the saucepan.

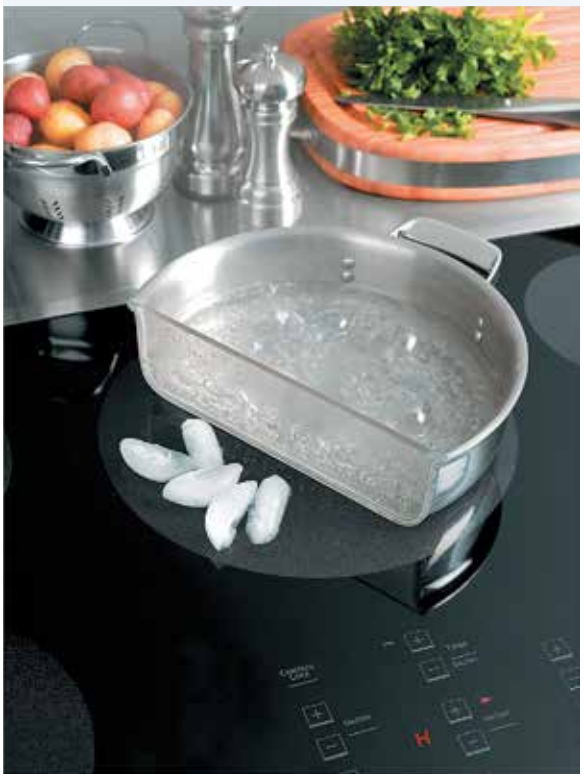
A comparison of the energy efficiencies of various cooktop technologies



(a) A single LED and (b) a torch incorporating several LEDs



In an induction cooktop, only the saucepan gets hot, resulting in less wasted heat and greater energy efficiency.



11.5.7 Designing an energy-efficient house

Designing a house with energy efficiency in mind involves incorporating features that keep the house warm in winter and cool summer with minimal use of appliances for heating and cooling. Minimising the need to heat or cool your home not only reduces your energy bills but also conserves fossil fuels and reduces greenhouse gas emissions.

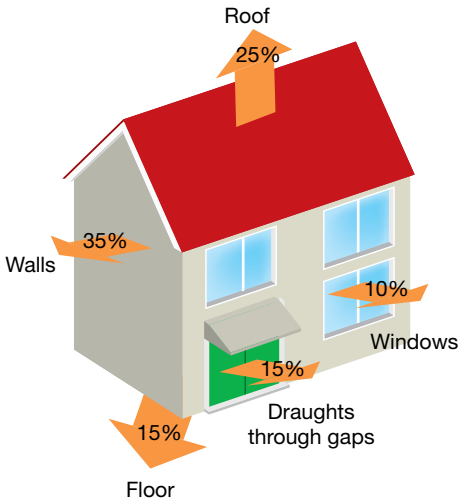
Controlling heat loss

In winter, heat tends to escape from a house by conduction, convection and radiation. Convection currents carry warm air up the walls and to the ceilings. Conduction transfers heat through these surfaces where it is radiated to the outside.

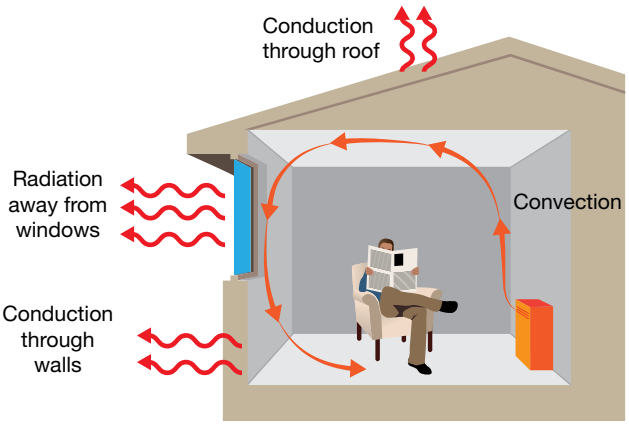
Heat loss by conduction through the ceiling and roof is reduced by insulation. Fibreglass batts are often used in insulation as they can reduce heat loss by up to 80 per cent. This is because air is a poor conductor and so air trapped between the glass fibres in the batt prevents heat escaping. Heat transfer by radiation can also be reduced by installing shiny foil in the roof to reflect radiant heat from the sun.

Insulating walls can also reduce heat loss. Double-brick homes have a cavity between the two layers of brick, which minimises heat escaping. Brick-veneer homes require insulation in the cavity to improve their energy efficiency. This may involve adding fibreglass batts between the layer of external

Percentage of heat loss in various parts of an uninsulated house



The transfer of heat in a house by conduction, convection and radiation



Installing insulation batts in the roof of a house



brick and internal panels. Concrete floors provide good insulation, which can be enhanced further by installing carpet and an underlay.

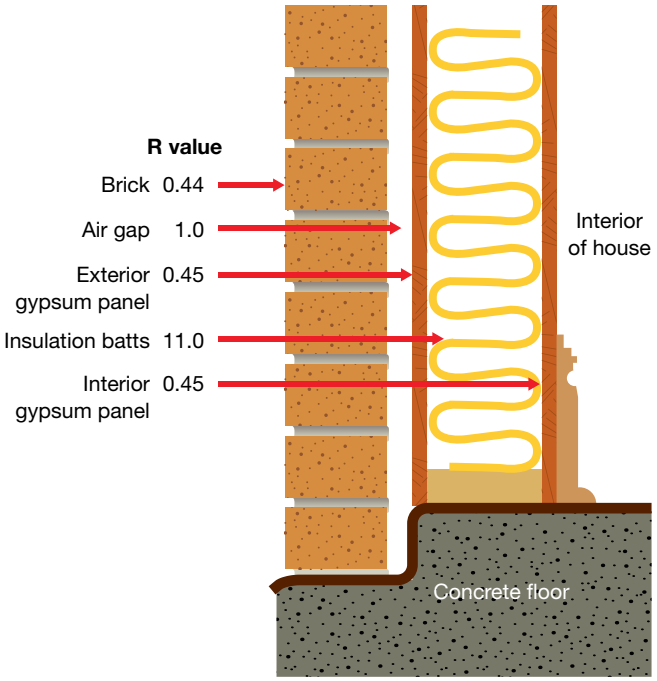
The conduction of heat out through windows can be reduced by installing double-glazed windows, which consist of two layers of glass separated by a narrow gap of air. Curtains are also useful in that they trap a still layer of air between them and the window. Reducing draughts around doors and windows can also minimise heat lost as warm air escapes.

Designing a house that takes into account the position of the sun can offer substantial benefits when heating is required in winter and cooling in summer. Large eaves around the roofline mean that in the summer, when the sun is higher in the sky, little direct sunlight strikes windows and the rest of the home, while in winter, when the sun is lower in the sky, sunlight is angled below the eaves, directly warming the home. Planting deciduous trees near north-facing windows allows heat to radiate through to the house in winter but not in summer. External shutters or louvres can achieve the same purpose.

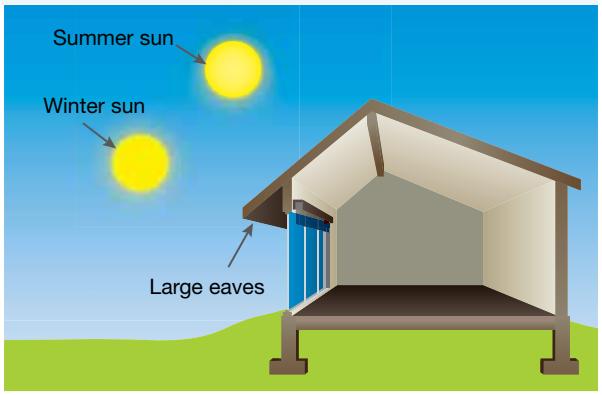
11.5.8 Natural heating and cooling

The sun offers a free and environmentally friendly source of heating. Many homes have solar electricity panels on their rooftops to generate electricity using photovoltaic technology. Others have installed solar water heaters to reduce their energy bills.

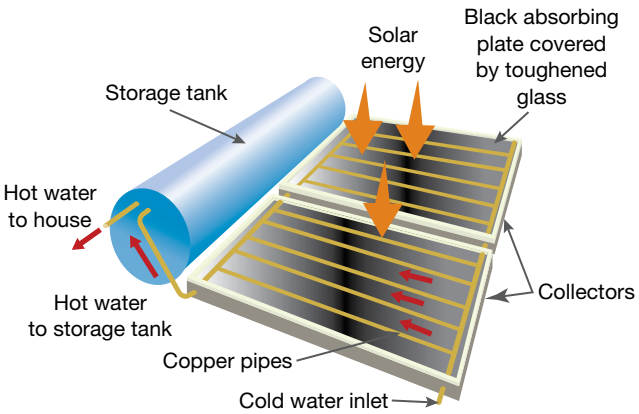
Features used to reduce the heat loss in a brick-veneer home. The R value for each feature is a measure of the resistance to heat flow and so is an indication of its insulating ability.



Large eaves on the north-facing side of a house keep the sun out in summer but not in winter.



In solar water heaters, energy absorbed by a black collecting plate heats water circulating in copper pipes beneath it. The heated water is pumped into a tank for storage.



A home solar water heater



INVESTIGATION 11.15

An energy-efficient house

AIM: To design an energy-efficient house

Use the principles of heat transfer and energy efficiency to design a house that is cool in summer and warm in winter.

Your design, drawn on a sheet of cardboard, should include:

- the type of construction, including the choice of building materials used for the roof, walls and floor
- how the house is positioned
- design features such as the size and location of windows, and the size of eaves
- soft furnishings, such as curtains
- landscaping, including the type of trees.

Label each energy-saving feature included in your design and, for each of these features, write a short reason for including it. This could be done underneath each label or listed in a separate section underneath your house design.

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. **Explain** how a traditional incandescent light globe works.
2. **Identify** two energy-efficient alternatives for lighting.
3. **Compare** the energy efficiency of induction cooking with gas and electric cooktops.
4. **Explain** why fibreglass batts are effective insulators.
5. **Explain** how foil placed in the roof improves the energy efficiency of a house.

Think

6. For each of the following devices, **identify**:
   (i) the original energy form
   (ii) the useful energy form created
   (iii) any wasted energy created.
   (a) Candle
   (b) Ipod or mp3 player
   (c) Guitar
7. **Calculate** the efficiency of a blender that converts 200 J of electrical energy to 120 J of kinetic energy and 80 J as heat per second.
8. **Explain** why compact fluorescent lamps should not be placed in glass recycling bins.
9. Homeowners often install roof ventilation. **Explain** how this improves the energy efficiency of a house.

Create

10. Induction cooktops tend to be more expensive than the more traditional gas and electric cooktops. With this in mind, design a brochure to advertise an induction cooktop, emphasising its energy-saving features.
11. The sun is angled approximately 35° from the horizontal in the winter and 80° in the summer. Draw a scale diagram of a house and windows to illustrate how eaves can maximise the use of the sun in both summer and winter.

11.6 Project: Going green

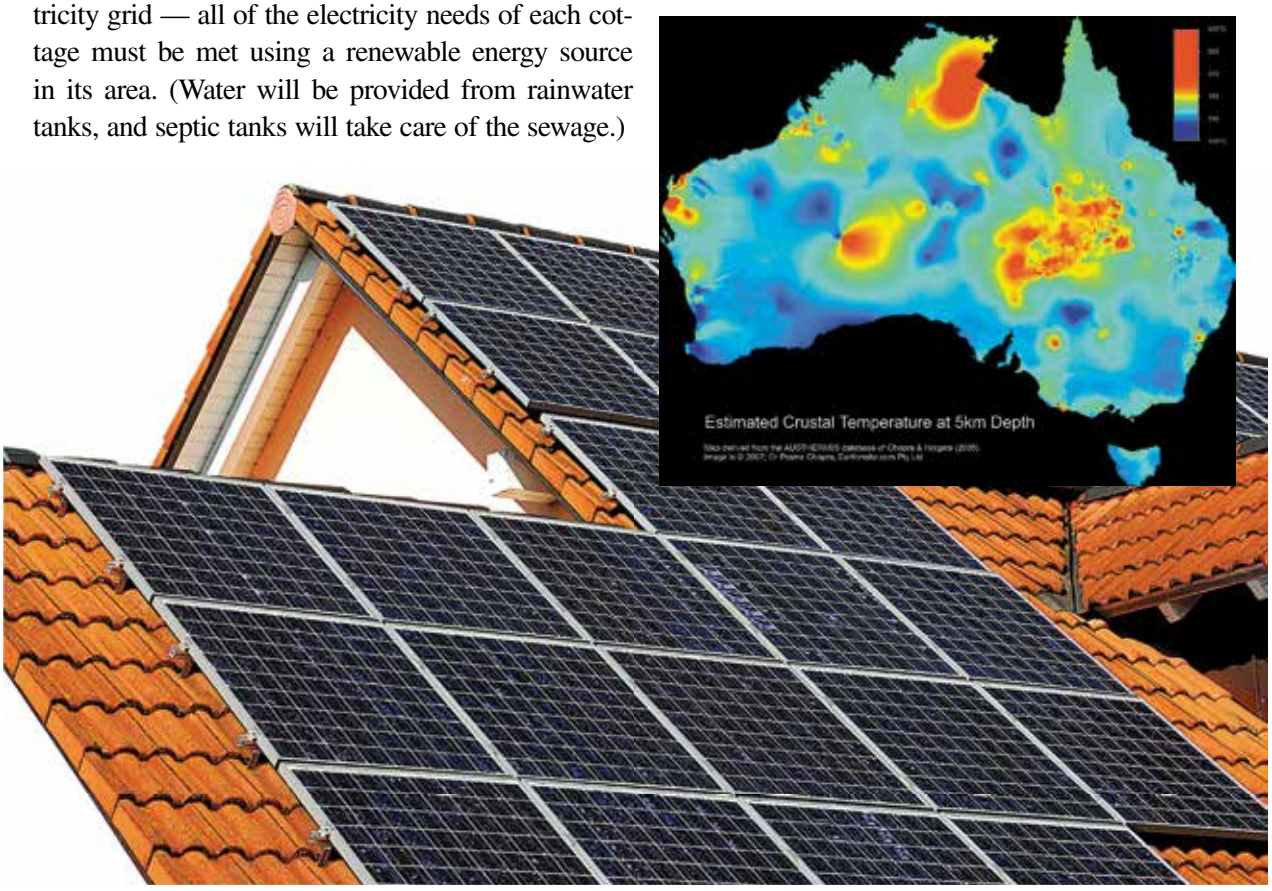
Scenario

As the supply of fossil fuels dwindles, cities become more crowded and anthropogenic global warming becomes an unavoidable reality, an increasing number of people are opting in to a more self-sufficient lifestyle. To meet this need, there is an increasing number of architecture and building firms that specialise in the design and construction of houses that are energy efficient and that are able to exist off the electricity grid indefinitely because they use electricity generation systems that meet all of the household's needs using renewable energy sources.

You and your team at Sustainable Housing Solutions have been approached by a potential client who wants to build a series of sustainable ecotourist cottages in remote locations across the country. To see whether your company should be awarded the lucrative contract to oversee the work on the whole chain of cottages, the client has asked you to make a presentation detailing how you would make one of these cottages as energy efficient and self-sustaining as possible. You can place this trial cottage anywhere in the country for your presentation purposes, provided that it is at least 100 km away from any town with a population greater than 5000 people.

Other criteria must also be met as follows:

- All of the cottages will have the same layout and will be constructed of mud bricks and have tiled roofs (you will be given a copy of the plan). While you can change the orientation and location of the cottage, you cannot change the design or these construction materials.
- Each cottage must have the following appliances: refrigerator, washing machine, stove, microwave, TV set, DVD player and stereo system. Smaller appliances such as toasters, shavers, hairdryers and computers may occasionally be used by guests as well.
- The cottages must be cool in summer and warm in winter; the client is not opposed to the idea of a reverse-cycle airconditioner or fans.
- There must be sufficient lighting to be able to read in every room.
- The cottages will not be attached to the national electricity grid — all of the electricity needs of each cottage must be met using a renewable energy source in its area. (Water will be provided from rainwater tanks, and septic tanks will take care of the sewage.)



Your task

Your team will prepare and deliver a report for the client that provides the following information:

- The best location to place the trial cottage (keeping in mind that it can be placed somewhere close to a source of renewable energy)
- Suggestions as to how the cottage can be made as energy efficient as possible
- A detailed estimate of how much electricity will need to be generated to power the cottage and run appliances
- A justified recommendation as to which renewable energy system should be used to generate that amount of electricity and how it would be supplied to the trial cottage
- An estimate of how much the energy system will cost, using costs for similar systems available on the internet as a guideline.

The report will take the form of an oral presentation with visuals (which may include PowerPoint slides, overhead transparencies and models). The presentation should be between six and eight minutes long.

Process

- Watch the introductory video lesson. You can complete this project individually or invite other members of your class to form a group.
- Find the Research Forum document in your Resources tab. Here you will find a number of different headings under which you will organise your research. You may delete those topics that you will not be considering or add your own topics if you find your research going in a different direction.
- Start your research. Make notes about information you think will be relevant to your project, entering your findings as articles under your topics 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 discover extra information about energy efficiency and self-sufficiency. You can view and comment on other group members' articles and rate the information they have entered. When your research is complete, print out your Research Report to hand in to your teacher.
- Find your client's house plan from the Documents section. The Resources tab also includes images and weblinks that you may find helpful for your project.
- Start putting your presentation together.





SUGGESTED SOFTWARE

- ProjectsPLUS
- Word or other word processing software
- PowerPoint
- Internet access

11.7 Review

11.7.1 Study checklist

Energy transformations

- **define** the term 'energy' 11.2
- **identify** different forms of energy and situations in which different forms of energy are evident 11.2
- **identify** objects that possess kinetic energy because of their motion, and quantify their kinetic energy 11.2
- **identify** objects that possess potential energy, and quantify the gravitational potential energy of an object 11.2
- **apply** the law of conservation of energy to account for the total energy involved in energy transfers and transformations 11.2

Heat and temperature

- **compare** the terms 'heat' and 'temperature' 11.3
- **describe** the transfer of heat by conduction, convection and radiation 11.3
- **analyse** situations in which heat is transferred by one or more of the following: conduction, convection and radiation 11.3
- **investigate** the ability of materials to prevent the transfer of heat 11.3
- **outline** the use of infra-red scanners 11.3

Electrical energy

- **outline** the essential elements of an electric circuit 11.4
- **compare** conductors and insulators 11.4
- **identify** symbols used in circuit diagrams 11.4
- **define** the terms 'series circuit' and 'parallel circuit' 11.4
- use circuit diagrams to represent simple series and parallel circuits 11.4
- **identify** the energy transfer taking place in an electric circuit 11.4
- **outline** how batteries provide circuits with electrical potential energy 11.4

Energy efficiency

- **identify** that most energy conversions are inefficient and lead to the production of heat 11.5
- **describe** advances in technology that have led to more energy-efficient lighting and cooking appliances 11.5
- **describe** solutions to address energy efficiency in house design and construction 11.5
- **describe** the benefits for society and the environment of advances in technology that have led to more efficient lighting, cooking and house design 11.5

Individual pathways

ACTIVITY 11.1
Revising energy
doc-10569

ACTIVITY 11.2
Investigating energy
doc-10570

ACTIVITY 11.3
Investigating energy further
doc-10571

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FOCUS ACTIVITY

online only

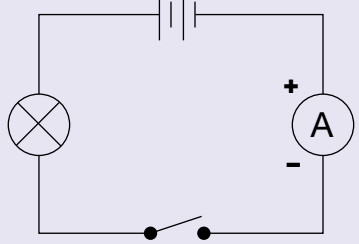
In what ways have developments in technology and increased knowledge led to improvements in devices that increase energy-use efficiency? Write a report on your findings.
Access more details about focus activities in this chapter in the Resources tab (doc-10568).

assessON

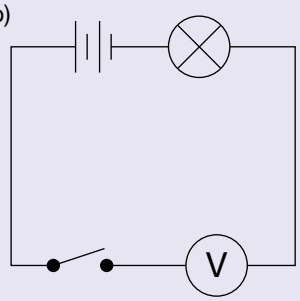
11.7 Review 1: Looking back

1. **Identify** the type of energy possessed by a:
   (a) bus on its way to school
   (b) wind-up toy before being released
   (c) gas heater.
2. **Describe** the Law of Conservation of Energy.
3. **Identify** the energy transformations that occur as:
   (a) a skier skis down a slope
   (b) a firecracker is ignited
   (c) a bungee jumper reaches the bottom of a jump.
4. **Calculate** the energy of:
   (a) a 65 kg bungee jumper about to jump from a height of 60 metres
   (b) an 800 kg car travelling 15 m/s.
5. In 10 minutes, an incandescent light globe is supplied with 1000 joules of electrical energy. During that time, the globe emits 400 joules of light energy along with 600 joules of heat energy. **Calculate** the efficiency of the globe in terms of light output.
6. **Compare** the particles in a beaker containing water at 67 °C with particles in another beaker containing water at 11 °C.
7. **Outline** the difference between heat and temperature.
8. Heat can move in three ways: conduction, convection and radiation. **Deduce** which method is most likely to transfer heat:
   (a) from the sun to the planets
   (b) from a person's feet to cold floor tiles
   (c) through the air
   (d) through water
   (e) from an open fire to your body
   (f) through a solid metal rod.
9. **Identify** the features of a thermos flask that control the movement of heat by conduction, convection and radiation, and **explain** how these features limit the transfer of heat by each of these methods.
10. A spatula of ammonium chloride crystals is added to 5 mL of water in a test tube. **Explain** why the water temperature drops from 22 °C to 15 °C within 3 minutes.
11. **Explain** why convection heaters are so effective in heating a room of a house.
12. Use symbols to draw a circuit containing two globes parallel with each other and with a battery. Place a switch in the circuit to operate both lights at the same time.
13. There is a mistake in each of the circuit diagrams below. Find the mistakes and then redraw the circuits correctly.

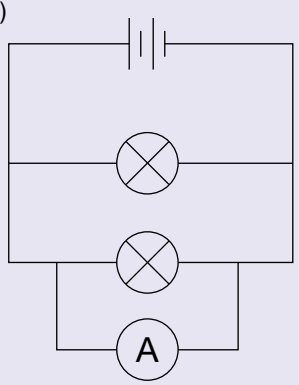
(a)



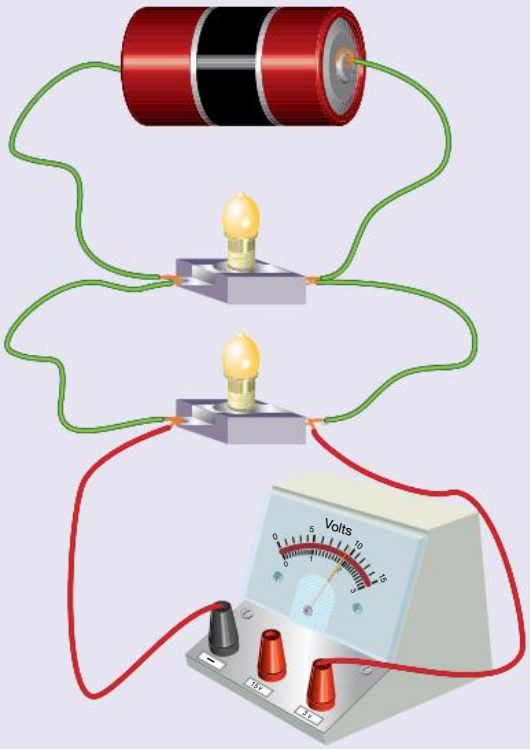
(b)



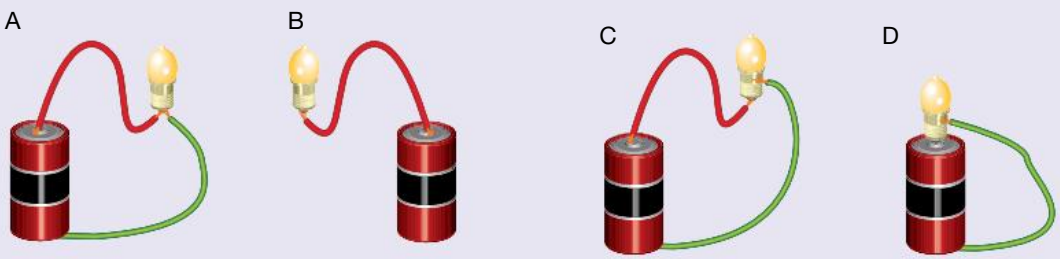
(c)



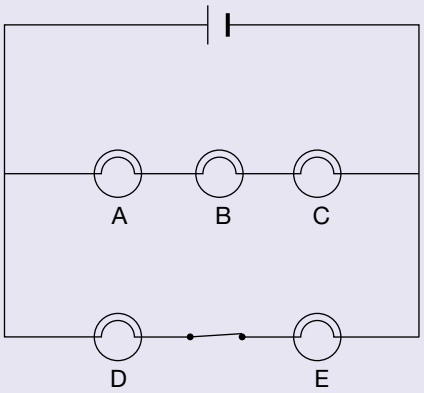
14. Using the correct symbols, draw this circuit as a circuit diagram.



15. **Explain** why the sale of incandescent light globes in Australia has been phased out.
16. Use the principles of heat transfer to **explain** why windows are often double glazed in in northern European homes.
17. **Identify** the main method or methods by which heat is transferred to the human body by:
    (a) a gas wall furnace
    (b) the sun
    (c) holding a hot plate
    (d) an open fireplace
    (e) walking on hot coals.
18. **Explain** why cooks often cover meat with aluminium foil instead of plastic.
19. **Explain** why solids such as polystyrene, foam, wool and fibreglass batts do not conduct heat as well as most other solids.
20. (a) Heat is always transferred from a region of high temperature to a region of lower temperature. **Explain** how your body is able to keep its core temperature at 37 °C even when the air temperature is greater than 37 °C.
    (b) **Explain** how wearing light, loose-fitting clothes protects your body from overheating in hot weather.
    (c) Why do your blood vessels get larger in hot weather?
21. In which one or more of the following arrangements will the globe light up?



22. Which two or more of the light globes in the circuit at right are connected:
    (a) in series with globe A
    (b) in parallel with globe A?



Test yourself

1. Energy is defined as
   (A) the ability to do work.
   (B) the temperature of an object.
   (C) the sum of the kinetic energy and potential energy of an object.
   (D) the amount of heat an object possesses. **(1 mark)**
2. In Australia, most electricity is generated from which source?
   (A) Hydroelectricity
   (B) Coal
   (C) Solar
   (D) Natural gas **(1 mark)**
3. The energy transformations that occur when an electric kettle boils water are
   (A) electrical energy to heat energy and kinetic energy.
   (B) potential energy to heat energy.
   (C) electrical energy to kinetic energy.
   (D) potential energy to heat energy and kinetic energy. **(1 mark)**
4. Matthew is cooking a sausage in a campfire using a pair of tongs as shown below. Heat can travel from the campfire to his hand by the processes of:
   (A) Conduction then convection
   (B) Radiation then conduction
   (C) Convection then conduction
   (D) Radiation then convection **(1 mark)**



5. **Describe**, with reference to examples, the benefits for society and the environment of advances in technology to improve the energy efficiency of appliances and the design and construction of homes. **(6 marks)**

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Complete this digital doc: Worksheet 11.10: Energy puzzles (doc-12445)

Complete this digital doc: Worksheet 11.11: Energy summary (doc-12446)

Complete this digital doc: Worksheet 11.12: Electricity puzzle (doc-12447)

Complete this digital doc: Worksheet 11.13: Electricity summary (doc-12448)

TOPIC 12
Chemical changes

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?

Chemical reactions are happening everywhere around us. They occur in batteries to provide electricity, in the oven when you bake a cake, in your hair when it is bleached or coloured, and in your car when it burns fuel. They even happen inside us, where chemical reactions enable food to be turned into energy and damaging chemicals to be made harmless. It really is a changing world – chemically changing!

LEARNING SEQUENCE

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12.9	Review	489

Chemical reactions can be colourful and explosive. These fireworks are the result of chemical reactions between metal salts and other compounds to produce different colours.



What is a chemical reaction?

You've probably already heard a lot about chemical reactions — at school, on television, at the movies or in books. But what is a chemical reaction, and how do you know whether a chemical reaction has taken place?

Check out the images on this page and answer the questions based on what you already know about chemical reactions.



1. The boiling liquid in the pot opposite is changing colour. It began as a mixture of reds, greens and blues and, after stirring, is changing into an dangerous-looking, yellow soup.
   (a) Write down your opinion about whether a chemical reaction is taking place.
   (b) Explain how you know whether a chemical reaction has taken place.
   (c) Is there a chemical reaction taking place underneath the pot? Explain your answer.
   (d) Clouds are forming above the pot. Is this evidence of another chemical reaction? Explain your answer.
2. Does a chemical reaction take place when you burn toast? What observations support your answer?
3. Does a chemical reaction take place when you toast bread without burning it? Explain your answer.
4. Is the frozen substance in the man's beard in the photograph below left the result of a chemical reaction? Explain your answer.
5. Runners in long-distance races sweat heavily. The water lost due to sweating evaporates from the skin. Is this evaporation an example of a chemical reaction? Explain your answer.
6. What happens when you use shampoo? Is this a chemical reaction?





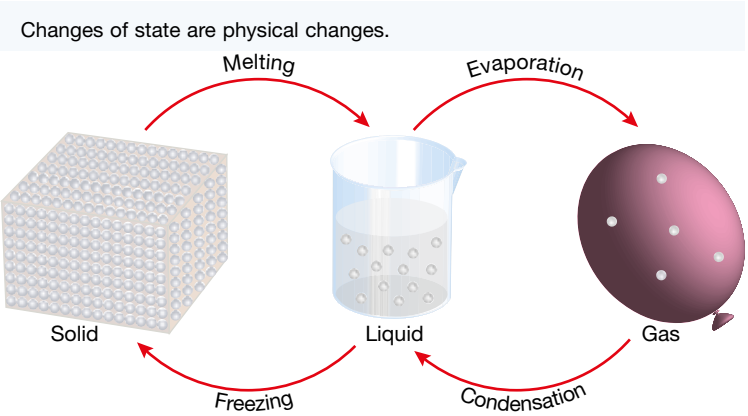




12.2 Time for a change?

12.2.1 Physical changes

Have you noticed the way that things change? When a tub of ice-cream is left on the table on a warm day, the ice-cream melts. When water is heated, it may turn into a vapour. When an apple is sliced, it turns brown. In topic 3, we looked at some of these changes when we studied the changes of state that matter may undergo as a result of adding or removing energy. For example:



- When energy is added to a solid, it melts to form a liquid. If we keep adding energy to the liquid, it boils or evaporates to form a gas.
- When we remove energy from a gas by cooling it, the gas condenses to form a liquid. If we keep cooling it, that liquid freezes to form a solid.

All of this may explain the ice-cream and the water, but does it explain why the sliced apple turned brown?

All of the changes of state we've described are physical changes. A physical change does not break any bonds between the atoms of a molecule or make different substances with different atoms. When water is in the form of ice, it is made up of water molecules, each of which is made up of one oxygen atom and two hydrogen atoms. When the ice is turned into water or into water vapour, it is still made up of water molecules.

Another characteristic of a physical change is that it is usually reversible. Water can be turned into ice and then back into water again very easily.

12.2.2 Chemical changes

Substances are said to have undergone a chemical change when the particles that make them up undergo change. Usually this occurs when the chemical bonds between particles in molecules are broken or when new chemical bonds are formed. There are a number of different ways that you can tell if a chemical change has occurred:

- A new substance is formed.
- A solid appears or disappears.
- The temperature of the substances changes spontaneously.
- A colour change occurs.
- Bubbles appear.
- A flame appears or light is produced.

When you hard-boil an egg, for example, you can see that a chemical change has taken place because the albumen has changed from a clear liquid to a rubbery white solid, while the yolk has changed from a translucent yellow liquid to a paler yellow, crumbly solid.

Most chemical changes are difficult to reverse. Once the egg has been cooked, you cannot turn it back into its raw state. Obviously a little commonsense is needed here though. For example, if you drop a raw egg and the shell breaks, you cannot reverse what has happened, yet this is not considered to be a chemical change.

When a sliced apple turns brown, this indicates that a chemical change has occurred to the surface of the apple. This particular change is a form of oxidation, a chemical reaction that we will look at in more detail later.

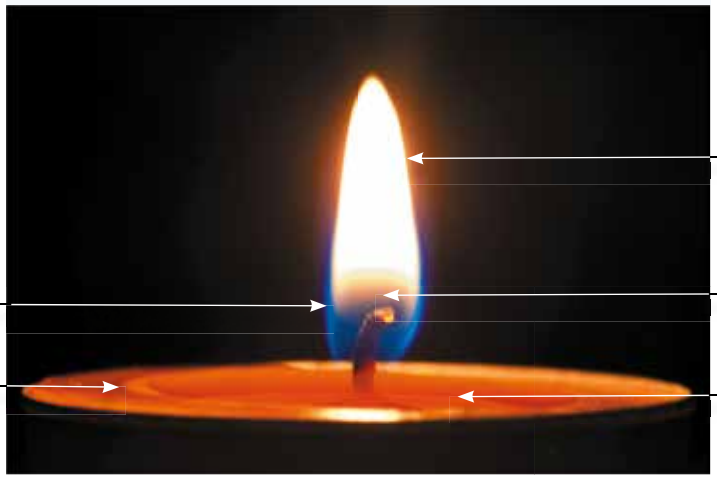
12.2.3 How does a candle burn?

Sometimes, a process that seems very simple is the combination of both physical and chemical changes. Let's look at the example of a burning candle.

When you try to light a piece of solid wax it melts, but it does not burn. If solid wax doesn't burn, how does a candle burn? Is it the string wick that is in the middle of the candle that burns? String burns, but it doesn't burn as a candle does. How then does a candle burn?

When you light the wick of a candle, the solid wax at the top of the candle melts to form a pool of liquid wax. This molten wax is drawn up through the wick by capillary action — the same process by which water soaks upwards through a piece of paper towel. At the top of the wick where the liquid wax is close to the flame's heat, it **evaporates**. Then, two different chemical reactions occur in which the wax vapour **reacts** with oxygen in the air as it burns. In the hottest part of the flame (where the flame is blue), carbon dioxide and water vapour are produced. In the bright yellow section of the flame, sooty particles of carbon, carbon monoxide and water vapour are produced. The carbon particles get hot enough to glow, producing light much in the same way that the hot filament in a light globe does. This is called **incandescence** and it is a physical change rather than a chemical one — once the sooty carbon rises far enough above the flame to cool down, it stops glowing.

The changes in a candle flame



12.2.4 How does a cake rise?

When an acid is added to bicarbonate of soda, a new substance — carbon dioxide gas — is produced. This process is a chemical change and is used in cakes to help them rise during the cooking process.

Baking powder is a mixture of bicarbonate of soda and cream of tartar. When baking powder is added to cakes, the cream of tartar dissolves in the liquids of the cake mixture and forms tartaric acid. This acid is then available to react with the bicarbonate of soda.

Self-raising flour contains baking powder so, when a recipe includes self-raising flour and a liquid, you know that the cooking process will involve a chemical change. The carbon dioxide gas produced during this chemical change rises through the cake mixture as it cooks and helps to aerate it.

INVESTIGATION 12.1

A burning candle

AIM: To investigate what happens when a candle burns

You will need:

safety glasses
candle
jar lid
matches
heatproof mat

- Place a jar lid on a heatproof mat.
- Light a candle and allow a drop of wax to drip onto the jar lid. Place the candle on the drop of wax and fix it to the jar lid.
- Observe the candle and write down as many observations of the burning candle as you can.
- Discuss your observations with others in your group.
- Blow out your candle and you will see the white vapour rising from the top of the wick.
- To confirm that the white vapour is not smoke, carry out the following test.
- Relight the candle. Once it is burning properly, blow it out.
- Quickly light the top of the vapour trail. The flame should run down the vapour to the wick and relight the candle.

Discussion

1. How far is the flame from the solid wax?
2. The solid wax has formed a little pool of liquid wax around the wick. Why has this happened?
3. Describe the odour of the vapour.

CAUTION: Do not smell the vapour directly. Fan the odour to your nose with your hand.

4. Draw a diagram of a candle and its flame. Label this diagram to explain how a candle burns.
5. Explain why lighting the wax vapour causes the candle to relight.

Describing change

Physical and chemical changes can be described using word equations.

For example, melting chocolate can be described by the equation:

solid chocolate → liquid chocolate

The burning of paper can be described by the equation:

paper + oxygen → smoke + ash

INVESTIGATION 12.2

How can you tell a chemical reaction has taken place?

AIM: To investigate changes during a chemical reaction

You will need:

110 g sugar
150 mL cold water
500 mL beaker
hotplate
stirring rod
220 °C thermometer
test tube
patty pans
heatproof mat
2 teaspoons of golden syrup
measuring cylinder

half a spatula of cream of tartar
half a spatula of bicarbonate of soda
laboratory coat and safety glasses

- Mix the sugar, cold water, golden syrup and cream of tartar in the beaker.
- Gently heat and stir the mixture over the hotplate until the sugar has completely dissolved.
- Stop stirring the mixture when it boils.
- Allow the mixture to reach 154°C, and then remove it from the hotplate.

CAUTION: The beaker and the mixture are very hot. Remove them from the hotplate with care.

- Dissolve the bicarbonate of soda in 1–2 mL of warm tap water in the test tube. Pour the dissolved bicarbonate of soda into the sugar mixture, stirring gently.
- Pour the hot mixture into patty pans.
- Allow to cool before examining.

Discussion

What evidence is there that a chemical reaction has taken place?

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. **Describe** the difference between a physical and a chemical change.
2. **Recall** two examples of physical change.
3. **Recall** two examples of chemical change.
4. **Identify** which term goes with each definition.

Definition	Term
Change from solid to liquid	Freezing
Change from gas to liquid	Melting
Change from liquid to solid	Condensation
Change from liquid to gas	Evaporation

5. **Recall** which type of physical change can always be reversed by heating or cooling.

Think

6. Copy and complete the table below.

Observation	Physical or chemical change
Water freezing to form snow	
A cake cooking	
Lighting the gas on the stove	
Petrol evaporating at the petrol pump	
Lighting a match	
Steam condensing on the bathroom mirror	
Melting gold to cast gold bars	
Dynamite exploding	
Bleaching a stain	
Dissolving eggshell in acetic acid	

7. Write two word equations to **describe** the changes of state that occur when a candle burns.
8. Write a word equation to **describe** the chemical change that occurs when a candle burns.

9. When you hard-boil an egg, the inside of the egg gets hard. **Explain** why this is a chemical change and not a physical change.

Create

10. Candles are a good example of both physical change and chemical change. Write a poem about a candle burning.

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Complete this digital doc: Worksheet 12.1: Physical and chemical changes (doc-12449)

12.3 Describing chemical changes

12.3.1 Chemical reactions

When a chemical change occurs, new substances are produced. The process of producing new substances is called a **chemical reaction**. Almost all the products you use or wear each day are made by chemical reactions: from cosmetics to concrete, plastics to paper, glass to graphite, stainless steel to shampoo, fibres to food additives, margarine to medicines and many, many more. You can usually tell that a chemical reaction has taken place if there is a change in colour, a gas is given off, heat or light is produced or a **precipitate** (cloudiness) appears.

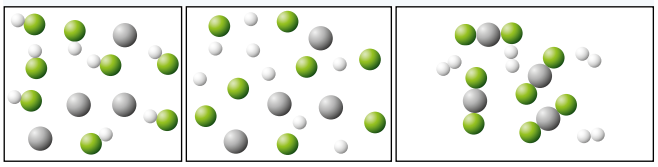
However, the only way to tell for sure that a chemical reaction has occurred is to identify the substances that are formed and establish that these are different from the original substances.

Reactants and products

In a chemical reaction, the substances that react together are called the **reactants** while the new substances that are formed are called the **products**. In a chemical reaction, the bonds between the atoms of the reactants break and new bonds are made between the atoms to form the products.

For example, the reaction between magnesium metal and hydrochloric acid is shown here.

The reaction between magnesium and hydrochloric acid produces the new substances magnesium chloride and hydrogen.



1. *Magnesium* is placed into *hydrochloric acid*.
2. Bonds between hydrogen and chlorine atoms break.
3. New bonds form. Chlorine atoms bond to magnesium atoms to form molecules of *magnesium chloride*, while hydrogen atoms bond together to form molecules of *hydrogen* gas.

KEY

Chlorine atom Hydrogen atom Magnesium atom

12.3.2 Chemical reaction experiments

Before you start each of the four experiments on these pages, design a suitable table for recording your observations.

As you do the experiments:

1. Make a note of the appearance of the reactants you are starting with.
2. Observe carefully to detect any changes that occur.
3. Describe the products of the reaction.



Safety glasses should always be worn during experiments involving chemical reactions.

INVESTIGATION 12.3

Magnesium metal in hydrochloric acid

AIM: To investigate the chemical reaction between magnesium and hydrochloric acid

You will need:

heatproof mat
safety glasses
test tube and test-tube rack
1 cm piece of magnesium ribbon
dropping bottle of 0.5M hydrochloric acid

- Put the magnesium into the test tube.
- Add 20 drops of hydrochloric acid to the test tube.

CAUTION: The test tube may become quite hot.

- Record your observations.

Discussion

What observation provides evidence that a chemical reaction has taken place?

INVESTIGATION 12.4

Heating copper carbonate

AIM: To investigate a chemical reaction in copper carbonate when heated

You will need:

Bunsen burner, heatproof mat and matches
test tube and test-tube rack
safety glasses
test-tube holder
spatula
copper carbonate powder

- Pour two spatulas of copper carbonate into the test tube.
- Using the test-tube holder, heat the test tube. Remember to move the test tube in and out of the flame and point the test tube away from people.
- Stop heating when the copper carbonate has changed colour.
- Record your observations.

Discussion

What observation provides evidence that a chemical reaction has taken place?

INVESTIGATION 12.5

Sodium sulfate and barium chloride

AIM: To investigate the chemical reaction between sodium sulfate and barium chloride

You will need:

heatproof mat
safety glasses
test tube and test-tube rack
test-tube holder
dropping bottle of 0.1M sodium sulfate solution
dropping bottle of 0.1M barium chloride solution

- Put 20 drops of sodium sulfate solution into the test tube.
- Add 20 drops of barium chloride solution to the test tube.
- Record your observations.

Discussion

What observation provides evidence that a chemical reaction has taken place?

INVESTIGATION 12.6

Steel wool in copper sulfate solution

AIM: To investigate the chemical reaction between steel wool and copper sulfate

You will need:

heatproof mat
glass stirring rod
safety glasses
1 cm ball of steel wool
test tube and test-tube rack
dropping bottle of 0.5M copper sulfate solution

- Put the steel wool into the test tube, using the glass stirring rod to push it gently to the bottom of the test tube.
- Add copper sulfate solution to the test tube to a depth of 2 cm.
- Record your observations.

Discussion

What observation provides evidence that a chemical reaction has taken place?

12.3.3 Word equations

In mathematics, relationships between numbers are written in the form of equations. In the same way, scientists can write chemical reactions in the form of chemical equations. The simplest form of chemical equation is the **chemical word equation**.

Chemical word equations are written so that the names of the reactants are shown on the left with the reactants separated by a plus sign (+). The reaction itself is represented by an arrow (→) that points to the products of the reaction. The names of the products formed are also separated by plus signs.

Each of the chemical reactions in the experiments on these pages can be described by a word equation.

1. When magnesium metal reacts with hydrochloric acid, hydrogen gas and magnesium chloride are formed:

magnesium + hydrochloric acid → hydrogen gas + magnesium chloride

2. Heating copper carbonate forms copper oxide and carbon dioxide:

$$\text{copper carbonate} \xrightarrow{\text{heat}} \text{copper oxide} + \text{carbon dioxide gas}$$

Although heat is required for this chemical reaction, it is not a substance and therefore is not a reactant. For this reason, 'heat' is written above the arrow.

3. The sodium sulfate and barium chloride in the solution react to form solid barium sulfate and sodium chloride, which remains dissolved in the solution:

$$\text{sodium sulfate} + \text{barium chloride} \rightarrow \text{solid barium sulfate} + \text{sodium chloride}$$

4. Steel wool (which is made of iron) dissolves in copper sulfate solution to form iron sulfate solution and copper metal:

$$\text{iron} + \text{copper sulfate solution} \rightarrow \text{iron sulfate solution} + \text{copper}$$

12.3.4 Types of chemical reaction

All of the millions of different chemical reactions that happen can be grouped according to the way in which the reactants combine to form the products. Some reactions can belong to more than one category of reaction.

In **decomposition** reactions, a reactant breaks up (or decomposes) to form two or more products. The decomposition is often the result of heating or passing electrical current through the reactant. For example, the Hofmann voltameter seen in chapter 9 decomposes water into hydrogen gas and oxygen gas using electricity:

$$\text{water} \xrightarrow{\text{electricity}} \text{hydrogen gas} + \text{oxygen gas}$$

However, substances such as hydrogen peroxide decompose over time without any stimulus at all:

$$\text{hydrogen peroxide} \rightarrow \text{water} + \text{oxygen gas}$$

A **synthesis** reaction is the opposite form of reaction to decomposition and occurs when two or more reactants combine to form a single substance. The formation of iron sulfide and sodium chloride are both examples of synthesis:

$$\text{iron} + \text{sulfur} \rightarrow \text{iron sulfide}$$

$$\text{sodium} + \text{chlorine gas} \rightarrow \text{sodium chloride}$$

Combustion reactions always have oxygen as a reactant. The burning of octane fuel in a car engine, the formation of rust and even respiration are all examples of combustion:

$$\text{octane} + \text{oxygen gas} \rightarrow \text{carbon dioxide} + \text{water}$$

$$\text{iron} + \text{oxygen} \rightarrow \text{iron oxide (rust)}$$

$$\text{glucose} + \text{oxygen gas} \rightarrow \text{carbon dioxide} + \text{water}$$

In a **displacement** reaction, metals combined with non-metals in the reactants swap partners to form new combinations. This can be seen in the following examples:

$$\text{silver nitrate} + \text{copper} \rightarrow \text{copper nitrate} + \text{silver}$$

$$\text{lead nitrate} + \text{potassium chloride} \rightarrow \text{potassium nitrate} + \text{lead chloride}$$

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. Write down four observations that could provide evidence that a chemical reaction has taken place.
2. When magnesium metal reacts with hydrochloric acid, hydrogen gas and magnesium chloride are formed.
   (a) **Identify** the products.
   (b) **Identify** the reactants.
3. What is the only real proof that a chemical reaction has taken place?
4. What happens to the atoms in the substances that take part in chemical reactions?
5. Name the four main types of chemical reaction.
6. How is synthesis different from decomposition?

Think

7. Write word equations for the following chemical reactions.
   (a) Methanol is burnt with oxygen in a spirit lamp to produce carbon dioxide and water.
   (b) Sodium metal reacts with chlorine gas to form sodium chloride.
   (c) Hydrogen gas and oxygen gas combine to form water.
   (d) Zinc metal dissolves in hydrochloric acid to form hydrogen gas and zinc chloride.
   (e) Hydrochloric acid reacts with copper to form copper chloride and hydrogen.
   (f) Methane and oxygen react to form water and carbon dioxide.
   (g) Water and sodium nitrate are formed when nitric acid reacts with sodium hydroxide.
8. **Explain** why the reaction that takes place when copper carbonate is heated is called a decomposition reaction.
9. **Identify** each of the following chemical reactions as synthesis, decomposition, burning or displacement reactions (remember that some reactions may be more than one type).
   (a) magnesium + oxygen → magnesium oxide
   (b) calcium carbonate → calcium oxide + carbon dioxide
   (c) potassium + chlorine gas → potassium chloride
   (d) magnesium + aluminium chloride → magnesium chloride + aluminium

Create

10. Performing some chemical reactions can be dangerous. Design a safety poster for one of the experiments you have done.
11. Choose one of the materials below and find out how it is manufactured. Write a report about the chemical reactions used in its production.
    - Glass
    - Soap
    - Margarine
    - Paper
    - Nylon
    - Polyethylene

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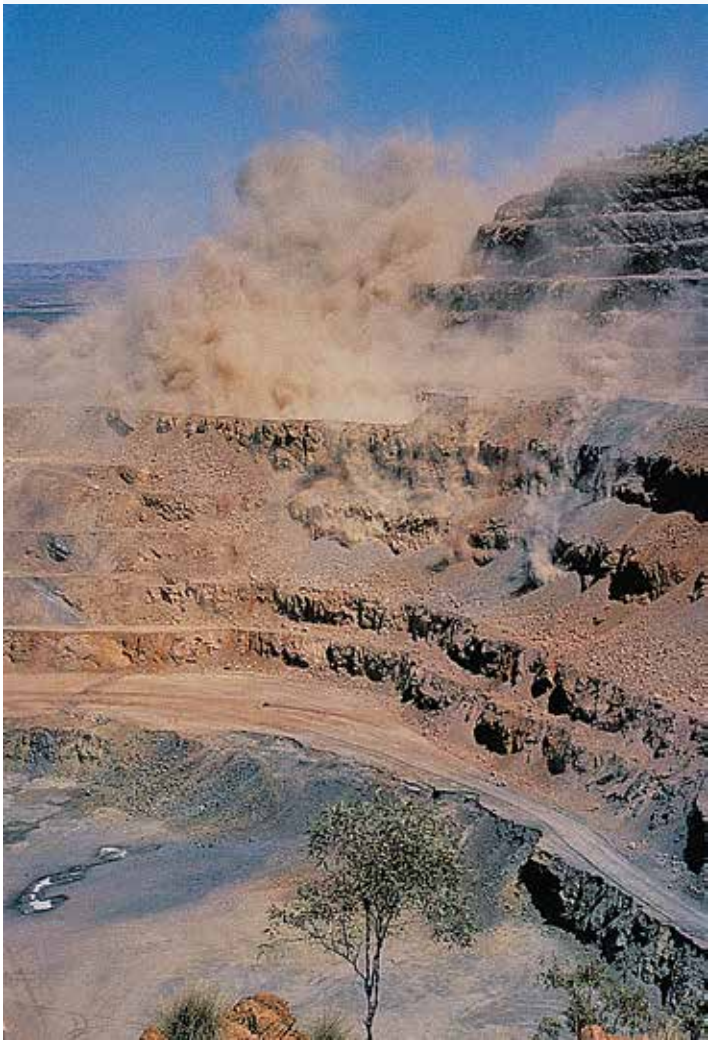
Complete this digital doc: Worksheet 12.2: Describing chemical changes (doc-12450)

12.4 Faster and slower

12.4.1 Rate of reaction

Not all reactions occur at the same rate. The speed with which a chemical reaction occurs is called its **reaction rate**. The explosive reaction between hydrogen and oxygen to form water is very fast and can release enough energy to propel spacecraft into orbit. Other reactions, such as the rusting of iron, can take weeks, months or even years to be complete.

Explosions are fast chemical reactions.



Sometimes it is important for the rate of a particular reaction to be either slowed down or made much faster than it would normally occur. There are a number of ways in which we can alter the rate of a chemical reaction.

12.4.2 Changing the temperature

You'll remember from our studies of the particle on pages 98–103 that adding energy in the form of heat causes the particles in a substance to move faster and to collide with each other more often. When particles collide, the bonds between atoms may break and new bonds may form. As the added heat increases the number of collisions, the breaking and creation of bonds occurs faster. In other words, the chemical reaction between substances occurs much faster if you heat them.

Of course, this works the other way as well; cooling the substances involved in a chemical reaction reduces the reaction rate. We make use of this fact when we store food in the refrigerator, rather than leaving it on the kitchen bench. Food goes off when micro-organisms produce chemical substances that degrade the food. Food is much cooler in the fridge than on the bench, and this reduces the rate at which the micro-organisms produce degrading substances.

INVESTIGATION 12.7

The effect of temperature on a reaction

AIM: To investigate the effect of temperature on reaction rate

You will need:

safety glasses
heatproof mat
Bunsen burner
matches
marble chips
test tube
test-tube rack
test-tube holder
dropping bottle of 1M hydrochloric acid

- Carefully slide one or two marble chips to the bottom of the test tube.
- Add hydrochloric acid to half-fill the test tube.
- Observe the reaction.
- Now gently heat the test tube and observe the reaction.

Discussion

1. Has a chemical change occurred? What evidence have you observed?
2. What effect did heat have on the rate of this reaction?
3. In this reaction, the calcium carbonate, which makes up the marble chip, reacts with the hydrochloric acid to form calcium chloride, water and carbon dioxide gas. Write a word equation for this chemical reaction.

12.4.3 Changing the surface area

Have you ever noticed that sugar in granular form dissolves much faster than a sugar cube when you add it to a cup of tea? When you break up a substance into smaller pieces, you increase the surface area of that substance. This means that more particles can immediately come into contact with the particles of another substance, allowing reactions between them to happen much faster.

Bath bombs, for example, are sold as solid balls that are dropped into your bath water to release carbon dioxide gas and scented oil. As the water reacts with the Epsom salts in the bath bomb, it slowly disappears. However, if you crush the bath bomb into a powder and then put it in your bath, it reacts very quickly.

Granular sugar dissolves faster than a sugar cube because it has a larger surface area.



12.4.4 Using a catalyst

Catalysts are chemicals that speed up chemical reactions. They are not reactants because they are not changed by the reaction. For example, catalytic converters in car exhausts use a precious metal, such as platinum, as a catalyst. This enables nitrogen oxide to react with toxic gases, such as carbon monoxide, to form the less harmful carbon dioxide and nitrogen gases; this reaction would not occur in the absence of platinum. This reaction can be shown as:

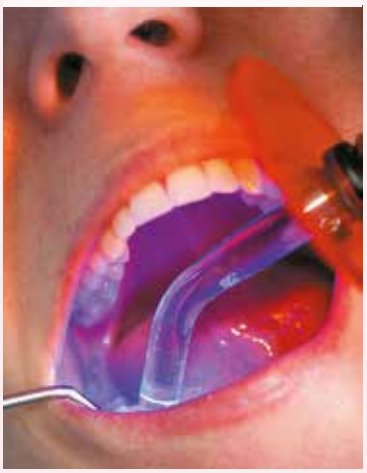
$$\text{carbon monoxide} + \text{nitrogen oxide} \xrightarrow{\text{platinum}} \text{carbon dioxide} + \text{nitrogen}$$

Catalysts produced by living organisms are called **enzymes**. Many of the chemical reactions taking place inside your body involve enzymes. Enzymes are also responsible for some of the changes we see in our food.

HOW ABOUT THAT!

Have you ever had a composite resin filling in your tooth? The dentist uses blue light or ultraviolet (UV) radiation to set this type of filling. The visible or UV light speeds up the reactions that cause the materials in the filling to harden. Without the UV light, you would be waiting for hours for this type of filling to set.

UV light can speed up the setting of a composite resin filling.



If you have ever left a half-eaten apple in your lunch box or locker, you've seen enzymes at work. Apples and other fruits go brown because chemicals in them, called **phenolics**, react with oxygen in the air. The brown chemicals produced are called **quinones**. Enzymes speed up the reaction.

The chemical word equation for this reaction is:

$$\text{phenolics} + \text{oxygen} \xrightarrow{\text{enzymes}} \text{quinones}$$

The human body produces many different enzymes to speed up the digestion of our food. Amylase helps us digest starches, protease is needed for protein digestion, and lipase must be present if we are to digest fats and oils.

Apples go brown when phenolics react with oxygen in the air.



12.4.5 Changing the concentration

The concentration of a solution depends on how much solute is dissolved in a set amount of solvent. The more solute that is dissolved, the greater the concentration of the solution is. The more concentrated that a solution is, the more particles of solute it contains that can react with other substances. If there are more particles available for a chemical reaction, the reaction will occur faster. So, use more concentrated solutions to make a reaction go faster, and use more dilute solutions to make a reaction go more slowly.

INVESTIGATION 12.8

Changing the reaction rate

AIM: To investigate how to change the rate of a reaction

You will need:

safety glasses
heatproof mat
test tubes and test-tube rack
white chalk
mortar and pestle
spatula
0.5M hydrochloric acid
1M hydrochloric acid
measuring cylinder

Hydrochloric acid reacts with chalk to produce carbon dioxide gas, water and calcium chloride.

- Put a small amount of chalk in a test tube and add enough hydrochloric acid to cover it. Observe the chemical reaction.
- Discuss with your partner how you could use this reaction to demonstrate one of the following hypotheses.
  (a) Increasing the concentration or amount of reactants speeds up a chemical reaction.
  (b) Increasing the surface area of reactants speeds up a chemical reaction.
  (c) Decreasing the concentration or amount of reactants slows a chemical reaction.

- Design your experiment and write down the method that you have chosen.
- Predict the results you would expect to obtain that would support the hypothesis you have chosen.
- Perform the experiment.
- Prepare a report of your findings.

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. **Define** the term 'rate of a chemical reaction'.
2. **Describe** four different methods of changing the rate of a reaction.
3. **Explain** how heating increases the rate of a reaction.
4. **Define** the term 'catalyst'.
5. **Explain** why a catalyst is not considered a reactant.
6. **Compare** enzymes and catalysts.

Think

7. Does a refrigerator stop food from rotting or does it just slow the rotting? **Explain** your answer.
8. Food keeps well in a refrigerator. **Deduce** why it keeps even longer in the freezer.
9. **Propose** why some washing powders contain enzymes.
10. **Deduce** why the word 'enzyme' appears over the arrow in the chemical word equation for the browning of fruit.

Investigate

11. Amylase, pepsin and lipase are all enzymes found in the human digestive system.
    (a) **Investigate** how they are involved in digestion.
    (b) Write a chemical word equation for the reactions that they speed up.

Use Data

12. In an experiment investigating how temperature affects the reaction rate of an unknown metal in acid, students collected the following data.

Temperature (°C)	Reaction time (seconds)
10	60
20	53
30	48
40	44
50	40
60	35
70	30
80	24
90	18

    (a) **Construct** a line graph that shows how increasing the temperature affected the reaction rate. Put temperature on the horizontal axis and time on the vertical axis.
    (b) **Predict** how long the reaction would take if the temperature was:
        (i) 65 °C
        (ii) 95 °C.
    (c) **Describe** the shape of the graph.
    (d) **Propose** a change to the experiment that would cause the reaction to occur faster.

13. Change the temperature, concentration and surface area in the **Reaction rates** interactivity in the Resources tab to see how they affect the rate of a reaction; then decide how the rates of particular reactions could be changed.

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Complete this digital doc: Worksheet 12.3: Speeding up reactions (doc-12451)

Tryout this interactivity: Reaction rates (int-0230)

12.5 Rusting is a chemical reaction

12.5.1 Corrosion

Corrosion is a chemical reaction between a metal and substances in its environment that results in the metal being 'eaten away'. The most common form of corrosion that we encounter is the corrosion of iron, a process referred to as rusting. Over time, rusting can cause enormous damage to buildings, bridges, ships, railway tracks and cars.

When iron reacts with water and oxygen in the air it forms iron oxide and other iron compounds that make up the familiar red-brown substance known as **rust**. Rusting is a chemical reaction that can be represented by the following word equation:

iron + water + oxygen → rust

Even strong buildings and bridges that are made from steel, an alloy of iron, are weakened by rusting. The Sydney Harbour Bridge, for example, is continually being painted to protect it from moisture and the air, which would cause its steel girders to rust. Ships and cars are also constructed largely of steel. Despite the strength of the steel, they need to be protected from the corrosive effects of the environment.

12.5.2 Speeding up rusting

Some substances in the environment make the rusting reaction happen much more quickly. One of the most effective of these is salt. Steel dinghies that are used in the ocean rust much faster than those that are used only in fresh water. This is because the salt in the water allows the reaction between the oxygen in the air and the iron in the steel to occur much faster.

Some chemicals released from factories may not be corrosive themselves but may allow the rusting process to occur faster. Even the exhaust from aircraft can speed up rusting. Research by the CSIRO has found that corrosion rates in a large city are highest near airports, industrial plants, sewage treatment works and large bodies of salt water.

Rusting is much slower in very dry environments such as deserts. In the Mohave Desert in southern California, hundreds of aircraft that are not in immediate use by

The planes in the Mojave Desert 'boneyard' are preserved from rusting by the dry desert air and low rainfall.



HOW ABOUT THAT!

City councils face problems caused by the action of dogs on metal lampposts. The corrosive properties of the dogs' urine rusts the steel of the lampposts a few centimetres above the ground.

airlines are stored in the open air. Due to the extremely low humidity — the rainfall is nearly zero — rusting occurs extremely slowly. As a result, some of the aircraft are still structurally sound despite being exposed for nearly twenty years!

INVESTIGATION 12.9

Observing rusting

AIM: To observe rusting under different conditions

You will need:

3 glass Petri dishes
fresh water
salt water
3 small beakers
steel wool without soap
permanent marker pen

- Set out your three Petri dishes. Half-fill the first dish with fresh water and the second dish with salt water. The third dish will be left unfilled at this stage.
- Place a small amount of steel wool in the middle of each of the Petri dishes.
- Turn the small beakers upside down and use them to cover the steel wool pieces.
- Mark the level of the water on the outside of the beakers for the first and second dishes.
- Construct a table in which you can record your observations over several days.
- Leave the Petri dishes in a safe place for three or four days. During this time, if needed, top up the fresh water and salt water in the dishes back to the marked lines.
- Observe the condition of the steel wool in each dish after four days and enter your observations in your prepared table.

Discussion

1. Did the water level change during the four-day period? If so, give a possible explanation for the change.
2. Which of the three samples of steel wool had (a) the most rust, (b) the least rust?
3. Does salt water cause rusting to occur faster than, slower than or at the same rate as fresh water?
4. Predict what would happen if the air had been completely removed from the three beakers for the duration of the experiment. Justify your response.
5. Suggest why people who live in seaside resorts have problems with their cars rusting.

12.5.3 Rust protection

The layer of rust that forms on an iron object flakes off the metal, allowing air and moisture to get through to the iron below. This causes more rusting to occur, and eventually the iron becomes a heap of rust. It is important to protect iron and steel from corrosion, especially if it is part of a bridge or the hull of a ship.

There are several ways to protect iron and steel from rusting. One way is to prevent oxygen or moisture from contacting the metal. This is called **surface protection**. The metal can be protected by coating it with paint, plastic or oil. If the surface protection becomes scratched or worn off, the metal below can be attacked by moisture and oxygen and rusting will occur. Examine the painted surface of an old car. Wherever the paint has chipped off you will find that corrosion has occurred and the rust can be seen.

Another way to protect iron from rusting is to coat it with a layer of zinc. This is called **galvanising**. Zinc is a more reactive metal than iron, which means that it is more likely to take part in chemical reactions. When zinc and iron are in the presence of moisture and oxygen, it is the zinc that reacts, leaving the iron unaffected. Many roofing materials and garden sheds are made from galvanised iron. You can also buy galvanised nails.

Rusting can be useful

Not all rusting is bad. You can buy, from a pharmacy, hand warmers, which are commonly used by skiers and campers. These packages produce heat when you shake them. The contents of the packet include powdered iron, water, salt and sawdust. When the packet is shaken vigorously, the iron undergoes a rusting reaction, which produces heat.

INVESTIGATION 12.10

Preventing rust

AIM: To investigate surface protection to prevent rust

You will need:

6 new iron nails
6 test tubes
test-tube rack
nail varnish and remover
vaseline
2 cm long strips of zinc, magnesium ribbon and copper
salt water
permanent marker pen

- Check that the nails do not show any signs of rusting; replace any that do.
- Put the test tubes in the rack and use the felt pen to number them 1 to 6.
- Prepare the nails as follows and then place them into separate test tubes.
  1. Nail left unaltered (this is your control)
  2. Nail painted with two coats of nail polish, letting it dry between coats
  3. Nail covered with a thick layer of vaseline or other grease
  4. Nail with magnesium strip coiled around it
  5. Nail with copper strip coiled around it
  6. Nail with zinc strip coiled around it
- Fill the test tubes with salt water so that the nails are completely covered. Mark the water levels with the pen.
- Leave for several days, adding salt water as required to keep the water level at the marks on the test tubes.
- Remove the nails and examine them closely, using the control for comparison. You will first need to remove the nail polish from nail 2 with nail polish remover and wipe the vaseline from nail 3.

Discussion

1. Rank the nails in order from least corroded to most corroded.
2. Which of the metals — magnesium, copper or zinc — prevented the formation of rust on the nail?
3. Describe the appearance of the magnesium, copper and zinc strips after they have been removed from their nails. Account for the changes in their appearance.

HOW ABOUT THAT!

When the Sydney Harbour Bridge was completed in 1932, it was initially given three coats of paint — 272 000 litres worth — to protect it from rust. However, as the paint is degraded by the UV radiation in sunlight, the bridge has needed to be continuously repainted ever since to maintain its rust-free condition. That's a lot of paint!



(left) Painting the Sydney Harbour Bridge is a never-ending job.

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. **Define** the terms 'corrosion', 'rusting and 'surface protection'.
2. **Explain** what galvanised iron is and what advantage it has over iron.
3. **Describe** the conditions that lead to rusting.
4. **Explain** why steel-hulled vessels used in the ocean rust faster than those used in fresh water.

Think

5. **Explain** why rusting occurs faster near Botany Bay than in areas further away from the sea.
6. **Discuss** how galvanising can protect iron from rusting if the zinc coating corrodes more quickly than the iron.
7. **Suggest** why the powdered iron in handwarmers used by skiers and campers rusts much more quickly than an iron nail.
8. When a car gets chips in its paintwork, why do you think it is important for them to be covered again either with paint or varnish?

Investigate

9. Do other metals corrode in the same way that iron does? Design an experiment to find the answer to this question using strips of copper, magnesium, zinc, lead and aluminium. Use sandpaper to remove any coating caused by corrosion from the metal strips; they should be shiny to start with.
10. Corrosion is found in many places. Survey your school for rust spots. **Account** for your findings.
11. If you have access to an old car, survey it carefully and record all the rust spots on the car. **Explain** why some parts of the car are more likely to rust.
12. Aluminium corrodes quite quickly, yet it is used to make soft-drink cans. **Investigate** why aluminium cans are not corroded by the drinks they store.
13. Use the **How rust works** weblink in the Resources tab to watch a video about rust and the corrosion of iron.

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Complete this digital doc: Worksheet 12.4: Rusting (doc-12452)

Explore more with this weblink: How rust works

12.6 Feel the burn

12.6.1 Burning

Burning is a chemical reaction that involves combining oxygen with a fuel, which usually produces heat and gases. Reactions that involve oxygen as a reactant are called **combustion** or **oxidation** reactions.

Many other oxidation reactions can occur. The rusting of iron to form iron oxide is an oxidation reaction. In fact, rusting could correctly be described as a very slow type of burning reaction!

HOW ABOUT THAT!

A *backdraught* occurs when a fire in a closed room dies down because it has been starved of oxygen, but flammable gases continue to stream out of the hot materials in the room. When a door to the room is opened, air is quickly drawn inside, restoring the supply of oxygen and allowing the fire to reignite. The resulting fire consumes all the flammable gases in a few seconds and produces sufficient heat to ignite any remaining materials in the room. This is very dangerous to firefighters.



12.6.2 Burning fossil fuels

When a **fossil fuel** reacts with oxygen, heat is produced, along with carbon dioxide and water vapour. Fossil fuels are those fuels that are formed from the remains of living things. Petrol, natural gas and coal are fossil fuels.

The oxyacetylene torch

To obtain temperatures as high as 3000 °C — hot enough to melt iron and weld metals — acetylene fuel is mixed with pure oxygen in an oxyacetylene torch.

acetylene + oxygen → carbon dioxide + water

The car engine

Car engines work by the combustion of petrol or gas in the cylinders. A mixture of air and fuel is drawn into each cylinder and ignited by a spark from the spark plug. The fuel reacts rapidly with oxygen in the air. The resulting explosion pushes the piston, which turns the drive shaft. The products of the reaction, carbon dioxide and water vapour, leave the car engine through the exhaust pipe.

Rocket fuels

Liquid and solid fuels are both used in spacecraft. When these fuels are burned, they provide sufficient thrust to launch a space shuttle into orbit hundreds of kilometres from Earth. Liquid hydrogen and liquid oxygen react to power the shuttle's main engines.

hydrogen + oxygen → water

Most of the thrust required to launch the shuttle into orbit comes from chemical reactions in the solid fuel, which is located in the solid rocket boosters. In space, liquid fuel such as hydrazine is oxidised to produce an enormous volume of gas. As the gas is released, the rocket is thrust forwards. By controlling the direction of the thrust, it is possible to steer the rocket.

An oxyacetylene torch is used in construction work.



Oxidation reactions provide the thrust to launch a space shuttle.



INVESTIGATION 12.11

Burning magnesium

AIM: To observe combustion of magnesium

You will need:

safety glasses
Bunsen burner, heatproof mat and matches
tongs
2 cm piece of magnesium ribbon
sandpaper

- If the magnesium ribbon is dull, use sandpaper to remove the dull layer.
- Hold the magnesium ribbon with tongs in the Bunsen burner flame.

CAUTION: Do not look directly at the flame — eye damage may occur.

- After burning the magnesium metal, observe the product of burning that is left.

Discussion

1. Describe the magnesium metal before burning.
2. During burning, the magnesium reacted with oxygen in the air by combining with it to form magnesium oxide. Describe the magnesium oxide.
3. How do you know that a chemical reaction has taken place?
4. Write a word equation for the chemical reaction.

INVESTIGATION 12.12

Burning paper

AIM: To observe the combustion of paper

You will need:

Bunsen burner, heatproof mat and matches
safety glasses
tongs
gas jar
limewater
paper
deflagrating spoon

- Pour 10 mL of limewater into the gas jar.
- Put a ball of scrunched-up paper into the deflagrating spoon.
- Light the paper and lower it into the gas jar.
- When burning has stopped, remove the deflagrating spoon and cover the jar.
- Shake the gas jar and observe the colour of the limewater.

Discussion

1. What happened to the limewater?
2. What gas was given off by the burning paper?

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. **Define** the term ‘burning’.
2. **Explain** what evidence there is that burning is a chemical reaction.

3. **Define** the term 'fossil fuel'. List three examples of fossil fuels.
4. List and **describe** three examples of useful oxidation reactions.
5. Write a word equation for each of the examples in question 4.
6. Is rusting an example of burning? **Explain.**
7. **Recall** the three different one-word names given to the chemical reactions in which fuels react with oxygen.

Think

8. Complete this word equation.
   fuel + _____ → _____ + **water vapour**
9. Name at least one fuel that is *not* a fossil fuel.
10. The hydrogen and oxygen used to launch space shuttles are cooled so that they are stored as liquids. **Explain** why the water produced in the reaction between the liquid hydrogen and liquid oxygen is in the form of a vapour rather than a liquid.
11. Can cell respiration be described as burning? **Explain**.

Investigate

12. Fire has always been present in Australia and is a major cause of change in the environment. Find out how Australian Aborigines traditionally used fire to benefit themselves and the environment.
13. Fire extinguishers are used to fight fires. One type of fire extinguisher, the soda–acid type, is commonly found in public buildings. When this fire extinguisher is turned upside down, a chemical reaction takes place inside the fire extinguisher to produce the liquid that spurts out of the nozzle. **Investigate** what is inside the soda–acid fire extinguisher and **explain** how it works. **Construct** a poster on how this fire extinguisher works.

Create

14. Choose one fuel from the list below and **construct** a poster on the use of this particular fuel. Include in your poster where it comes from, what it is used for and a word equation for its oxidation reaction.

methane	ethanol
butane	propane
kerosene	lignite
diesel	acetylene

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Complete this digital doc: Worksheet 12.5: Combustion (doc-12453)

12.7 Acids and bases

12.7.1 Acid and bases

Acids and **bases** are two groups of chemicals that affect you every day. In your stomach, acids help to digest your food, and, in your mouth, bacteria produce acids that can destroy the enamel of your teeth. Most cleaning agents, including soap, are bases that can dissolve oil and grease from surfaces.

Some common acids and bases are found around the home.



In industry, acids are used to produce a wide range of products including drugs, explosives, fertilisers and plastics.

The products shown in the photographs below are examples of acids and bases that can be found around the home.

12.7.2 Sour and bitter

Many of the foods you eat contain acids. Tomatoes, citrus fruits, vinegar and lemonade are all acidic. Acids have a sour taste; in fact, the name acid comes from the Latin word *acidus* meaning 'sour'. Some acids, like the acid found in car batteries (sulfuric acid), are very **corrosive**. They react with solid substances, 'eating' them away.

Bases have a bitter taste and feel slippery or soapy to touch. Some bases are very corrosive, especially caustic soda (sodium hydroxide). Caustic soda breaks down fat, hair and vegetable matter and is the main ingredient in drain cleaners. Other bases are used in soap, shampoo, toothpaste, dishwashing liquid and cloudy ammonia as cleaning agents. Bases that can be dissolved in water are called **alkalis**. Some common acids and bases are listed in the tables below.

Acid–base **indicators** are substances that can be used to tell whether a substance is an acid or a base. Some common indicators are listed in the table below. Acid–base indicators react with acids and bases and produce different colours in each. Some of them are natural dyes, while others are artificially made.

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 • Used in the food industry and the manufacture of some pharmaceuticals
Carbonic acid	• Formed when carbon dioxide gas dissolves in water • Present in fizzy drinks
Acetic acid	• Found in vinegar • The production of other chemicals, including aspirin

Base	Uses
Sodium hydroxide (caustic soda)	• The manufacture of soap • As a cleaning agent
Ammonia	• The manufacture of fertilisers • As a cleaning agent
Sodium bicarbonate	• To make cakes rise when they cook

Indicators and their colours in acids and bases

Indicator	Colour in acid	Colour in base
Methyl orange	Orange	Yellow
Litmus (made from lichens)	Red	Blue
Bromothymol blue	Yellow	Bluish-purple
Phenolphthalein	Colourless	Pink
Red wine	Red	Green
Red cabbage juice	Red	Yellow

HOW ABOUT THAT!

Cochineal is a red dye made from the dried and ground-up bodies of female scale insects (*Dactylopius coccus*). These insects live on cactus plants in Mexico. Cochineal is used as a food colouring but is also an acid–base indicator.



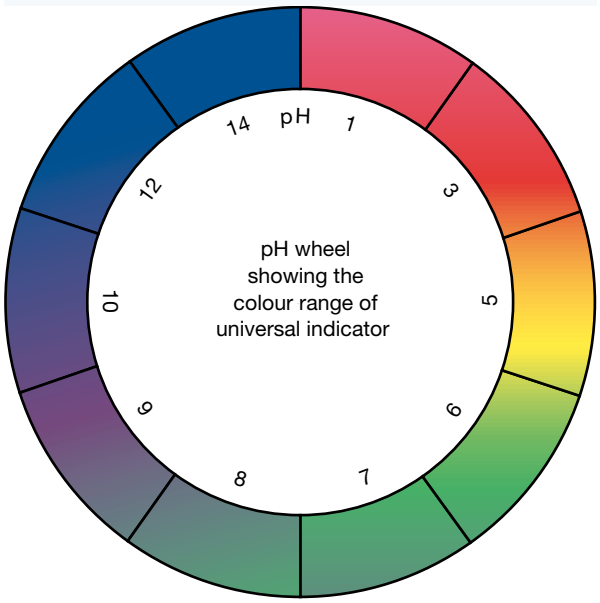
An unusual indicator — *Dactylopius coccus*

12.7.3 Measuring pH

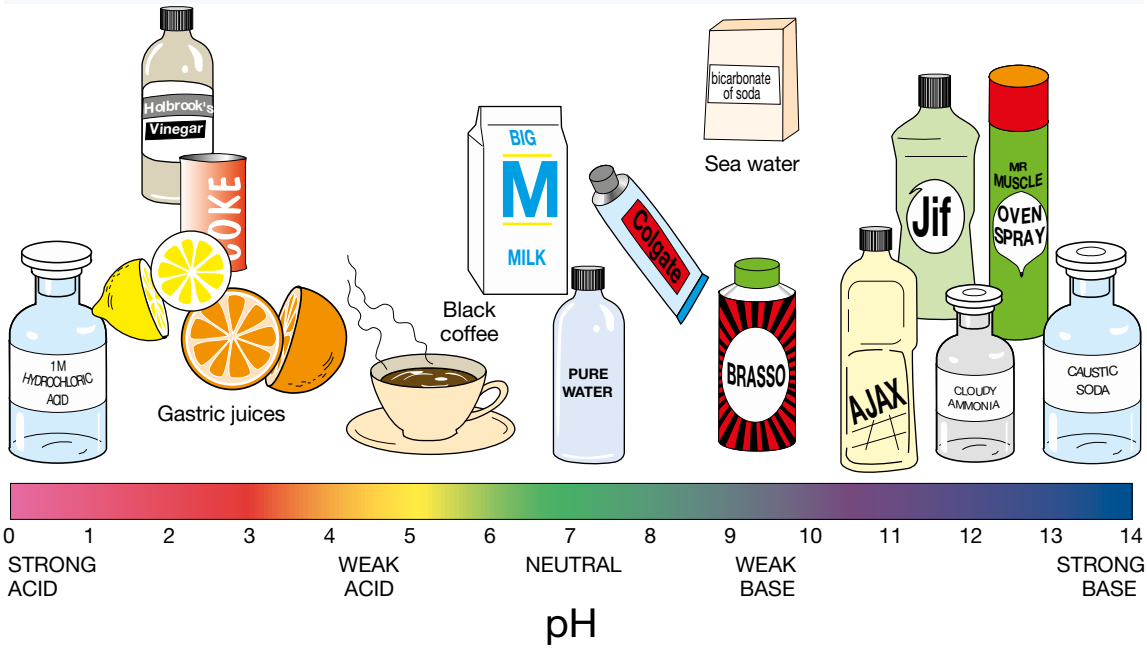
You can describe how acidic or basic a substance is by using the numbers on the **pH scale**. The pH scale ranges from 0 to 14. Low pH numbers (less than pH 7) mean that substances are acidic. High pH numbers (more than pH 7) mean that substances are basic. If a substance has a pH of 7 it is said to be neutral — neither acidic nor basic. This is shown on the pH scale below. 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).

pH can be measured using a pH meter or a special indicator called universal indicator. Universal indicator is a mixture of indicators and it changes colour as the strength of an acid or base changes. The colour range of universal indicator is shown at right.

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).



The pH values of some common substances



Garden-grown indicators

Hydrangeas are a popular hedging plant in Australia, producing clusters of flowers. While white hydrangeas stay the same colour all the time, the flowers of the coloured variety change shade according to the pH of the soil in which it is growing. If the soil has a pH of about 5 or less, the hydrangea's flowers will be blue-violet. As the soil becomes less acidic, the flowers change to a bright pink. The colours of the hydrangeas can be purposely changed over a few months by adding different substances to the soil. If you add iron or aluminium sulfate to the soil of a pink hydrangea, the flowers will become blue. If you have blue flowers and want them pink, calcium carbonate can be added.

Hydrangeas are pH sensitive.



12.7.4 Neutralisation reactions

When an acid and a base react with each other, the products are neither acids nor bases. Such a reaction is called a **neutralisation** reaction. Water is always one of the products of a neutralisation reaction. The word equation for a neutralisation reaction is:

acid + base → salt + water

Sometimes, a gas is produced as well as a salt and water. For example, when hydrochloric acid is added to sodium hydroxide, water and sodium chloride are produced. Both of these substances have a neutral pH:

hydrochloric acid + sodium hydroxide → water + sodium chloride

To neutralise something means to stop it from having an effect. To stop an acid from having an effect, a base can be added to it. Similarly, to stop a base from having an effect, an acid can be added. So, the pain caused by the acidic sting of an ant can be relieved by adding a weak base, such as sodium bicarbonate (baking soda). Adding a weak acid such as vinegar can relieve the pain caused by the alkali in the sting of a wasp.

HOW ABOUT THAT!

Indigestion is a very old problem and, without 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 of four sugar cakes, which they 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.

12.7.5 When your stomach rumbles

Have you ever had **indigestion**? Do you burp? Does your stomach rumble? These things happen as a result of the chemical reactions in your stomach.

Your stomach contains hydrochloric acid, which helps food digestion. However, if it becomes too acidic you may experience a burning feeling. This is called indigestion. The treatment for indigestion is to take an **antacid** powder or tablet. An antacid contains a base, which neutralises the excess acid in the stomach and relieves the pain. As in all neutralisation reactions, a salt and water are produced. One commonly used antacid is milk of magnesia. It consists of a solid base, magnesium oxide suspended in water. The base reacts with the hydrochloric acid in your stomach. The word equation for this chemical reaction is:

$$\underset{\text{base}}{\textbf{magnesium oxide}} + \underset{\text{acid}}{\textbf{hydrochloric acid}} \rightarrow \underset{\text{salt}}{\textbf{magnesium chloride}} + \textbf{water}$$

The products are magnesium chloride (a salt), and water.

INVESTIGATION 12.13

Antacids

AIM: To investigate the effect of an antacid on pH

You will need:

safety glasses
heatproof mat
100 mL conical flask
universal indicator
0.05M hydrochloric acid solution
spatula
antacid powder (e.g. Eno salts or Mylanta)

- Pour some hydrochloric acid into the conical flask.
- Add 2 or 3 drops of universal indicator.
- Note the colour of the solution, and determine its pH.
- The acid in the conical flask represents the stomach fluids.
- Add a spatula of antacid powder to the conical flask and gently swirl the flask.
- Observe the reaction and note the colour of the solution and the pH.

Discussion

1. What happened to the pH of the solution when the antacid was added?
2. Was the level of acidity reduced by the antacid?

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. **Recall** at least three uses of acids and three uses of bases.
2. How can acids be **distinguished** from bases?
3. **Compare** the common properties of some acids and bases.
4. **Describe** the difference between a base and an alkali.
5. What is a neutralisation reaction?
6. **Recall** which acid or base is used:
   (a) to make cakes rise
   (b) in fizzy drinks
   (c) in drain cleaners
   (d) in vinegar
   (e) in cleaning agents
   (f) in car batteries.

7. **Define** the term 'acid–base indicator'.
8. **Explain** how antacids relieve indigestion.
9. **Explain** what causes the burning sensation in your stomach when you have indigestion.
10. **Recall** which type of substance has a pH value:
    (a) less than 7 (b) more than 7 (c) equal to 7.

Think

11. When you take antacid tablets for an upset stomach, does the pH of your stomach contents increase or decrease? **Explain** your answer.
12. What is the pH of soil that produces pink hydrangeas?
13. Is aluminium sulfate an acid or a base? **Explain** your answer.
14. Some antacids containing calcium carbonate produce a gas as they work, making you burp. What gas is most likely produced?
15. What would be the result of putting vinegar on a bee sting?
16. **Explain** why our stomachs are not damaged when we consume acidic food and drinks.

Create

17. Design and **construct** a hazard warning label for a:
    (a) bottle of concentrated hydrochloric acid
    (b) car battery
    (c) bottle of drain cleaner that contains mainly caustic soda.

Use data

18. A pH meter was used to measure the pH of five different substances, and the results are shown in the table below. **Identify** which substance could be:
    (a) a weak base
    (b) vinegar
    (c) pure water
    (d) a strong base.

Substance	A	B	C	D	E
pH value	6.0	12.0	3.0	7.0	8.0

19. Which two of the substances in question 18 would you expect to be the most corrosive? **Justify** your answer.
20. **Construct** a bar graph to display the pH values of the five substances in question 18.

Investigate

21. **Investigate** what a peptic ulcer is, how it is caused and how it can be treated.
22. Play the **pH rainbow** interactivity in the Resources tab and drop liquids in their correct positions on the pH scale.

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Complete this digital doc: Worksheet 12.6: Acids and bases (doc-12454)

Try out this interactivity: pH rainbow (int-0101)

12.8 Acid rain

Science as a human endeavour

12.8.1 What causes acid rain?

It's hard to believe that rain is responsible for the deterioration of the statue in the picture opposite. Of course, this isn't just normal rain but **acid rain** — rain that has a very low pH. In heavily industrialised areas of the world, acid rain is a huge problem not just for the damage that it does to statues and buildings

but also for the entire ecosystem of these regions. Forests, crops and lakes in neighbouring non-industrial regions are also affected by acid rain blown in from industrial areas.

You can see the damaging effects of acid rain on this statue.



1908 **1969**

While distilled water is neutral (pH = 7), normal rain is slightly acidic with a pH of about 5.7. This is because the rain reacts with carbon dioxide in the air to produce a dilute form of carbonic acid — the same acid that forms in fizzy soft drinks:

water + carbon dioxide → carbonic acid

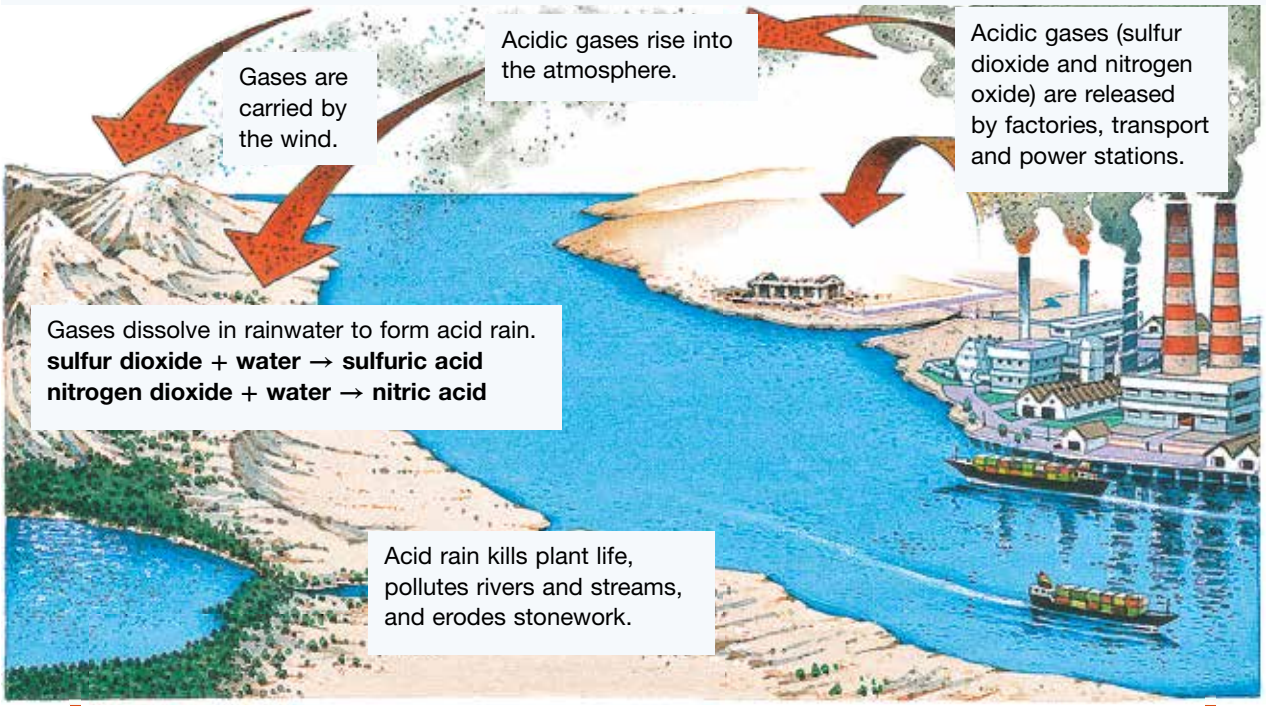
However, if concentrations of sulfur dioxide and nitrogen oxide in the atmosphere are high, these gases react with water in the air to produce sulfuric, nitric and other acids. When the rain falls, it is far more acidic than it would normally be and is known as acid rain. The lowest pH recorded for acid rain is 2.1.

If acid rain falls as snow, **acid snow** can build up on mountains. When this snow melts, huge amounts of acid are released in a short time into waterways.

12.8.2 Where do the gases come from?

Most of the gases that cause acid rain come from the burning of fossil fuels (natural gas, oil and coal) in industry, power stations, the home and cars. North America and Europe have a greater problem with acid rain because they use coal with a higher sulfur content than Australian coal. The sulfur dioxide released by volcanoes also contributes to acid rain.

The formation and effects of acid rain





When acid rain eats into buildings and statues, it is reacting with calcium carbonate in the marble or limestone.

calcium carbonate + acid rain → gypsum + water + carbon dioxide

The gypsum formed by acid rain on a statue is a powdery dust (calcium sulfate), which is washed away by the rain and the statue is slowly eaten away.



Acid rain damages the cells on the surface of leaves and affects the flow of water through plants. It also makes plants more likely to be damaged by frosts, fungi and diseases. In northern Europe, entire forests have died as a result of acid rain.



Acid rain collects in streams, rivers and lakes, making the water more acidic. Acid rain causes the pH of lakes to fall. Some aquatic plants and animals cannot tolerate these acidic conditions and die.

'Dead lakes' are lakes and water bodies in which the pH of the water has been reduced so much by acid rain falling into them that they no longer support animal or plant life. These lakes may have a pH as low as 4.1.

INVESTIGATION 12.14

Investigating acid rain

AIM: To model the effect of acid rain on plant growth

Design and carry out an experiment to investigate the effect of acid rain on the growth of plants.

You will need:

empty milk cartons
potting soil
distilled water
vinegar (or 0.1M hydrochloric acid solution)
measuring cylinder
seeds (such as lucerne, peas, cress and beans)
universal indicator

- Cut the milk cartons so that they are about 10 cm high. These will make suitable containers for growing the seeds, five seeds per container.
- Test the effect of water with different pH values on the growth of the seeds. To ensure that your tests are fair, you will need to keep everything the same in your experiment, except the one thing that you are varying. In this case you are varying the acidity (pH) of the water that you are putting on the plants.
- Prepare a report on your investigation. This could be a written report, a video, a wall chart or an oral presentation.

12.8.3 Solving the problem

The problem of acid rain and all the damage that it causes can be solved only by reducing the release of acidic gases into the air. Some ways of doing this include:

- looking for alternative ways of producing electricity
- encouraging people to use public transport or to car pool.
- using low-emission vehicles
- ensuring that all industrial chimneys are fitted with well-maintained emission scrubbers
- coal 'cleaning', in which coal is pulverised and sulfur-laden minerals are removed
- using low-sulfur coal in power plants
- fluidised bed combustion, a process where coal is passed over a bed of limestone as it is burned, allowing sulfur dioxide to be absorbed and, therefore, decreasing the amount of sulfur entering the atmosphere.

HOW ABOUT THAT!

The connection between atmospheric pollution and acidic rain was first made in Manchester in 1852 by the Scottish chemist Robert Angus Smith. However, the term 'acid rain' was not actually used until the 1970s when the phenomenon became more common.

12.8 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.

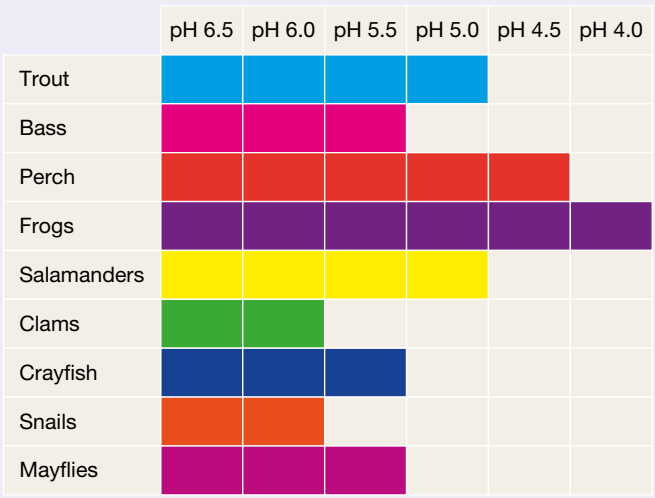
Remember

1. **Define** the term 'acid rain', and **explain** how it is produced.
2. **Explain** why rain is slightly acidic even without air pollution.
3. **Describe** two different ways in which acid rain can harm the plants and animals in streams and lakes.
4. Complete this word equation.

   acid rain + calcium carbonate → _____

Think

5. Motor vehicles make a large contribution to the acid rain problem. Most of them use fuel that releases acidic nitrogen oxides when it is burned. Write an account that **discusses** how motor vehicle pollution could be reduced over the next thirty years.
6. The diagram below shows the organisms that are normally found in a particular lake and the pH of water that they are able to tolerate.



(a) Which of these species would start to die first if the lake water started to increase in acidity?
(b) Which of the species is the most tolerant of high acid levels in the lake? **Explain**.
(c) Which species would remain if the acidity of the lake water increased until it had a pH of 5.0?

Create

7. Write a newspaper article that **analyses** the devastation caused by acid rain.
8. **Construct** a wall chart that explains how acid rain is formed in our environment and the damage that it can cause.

Investigate

9. Use the library to **investigate** which countries are most affected by acid rain.
10. **Investigate** how damage caused by acid rain could be stopped or at least reduced.
11. Flue gas desulfurisation 'scrubbers' are used to remove sulfur dioxide from burned coal, reducing the amount that enters the atmosphere. Research this process and answer the following questions.
    (a) What are the main components of these scrubbers?
    (b) What are the government guidelines concerning the fitting of these devices to industrial chimneys? Are they compulsory in Australia?
    (c) What volume of sulfur dioxide is produced by factories and power stations in Australia? How does the volume compare with that produced by other countries?
    (d) What penalties are levied against producers of emissions? Which government department or authority is in charge of investigating polluters?

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Watch this eLesson: The rain is burning! (eles-0065)

Complete this digital doc: Worksheet 12.7: Acid rain (doc-12455)

12.9 Review

12.9.1 Study checklist

Chemical changes

- **recall** the physical changes that matter may undergo 12.2
- **compare** a chemical change with a physical change 12.2
- **define** the term 'chemical reaction' 12.3
- **describe** how you can tell if a chemical reaction has taken place 12.3

Describing reactions

- **construct** word equations to describe chemical reactions 12.3
- **define** the term 'precipitate' 12.3
- **distinguish** between reactants and products 12.3
- **identify** the reactants and products in word equations 12.3
- give two examples each of combustion (oxidation), synthesis, decomposition and displacement reactions 12.3

Reaction rates

- **define** the term 'reaction rate' 12.4
- **describe** processes that allow the rate of a chemical reaction to be changed 12.4
- **distinguish** between processes that speed up a reaction and those that slow a reaction 12.4
- **explain** why increasing temperature, surface area or concentration makes a reaction occur faster 12.4

Common reactions

- **explain** the process of rusting 12.5
- **compare** rusting and combustion 12.5, 12.6
- **describe** how rusting can be prevented or slowed 12.5
- **construct** word equations to describe common oxidation reactions 12.6

Acids and bases

- **distinguish** acids from bases and alkalis 12.7
- **describe** the function of acid–base indicators and give three examples of these indicators 12.7
- **identify** acids, neutral substances and bases (alkalis) according to their pH 12.7
- **explain** how antacids settle a rumbling stomach 12.7
- **describe** what is meant by neutralisation 12.7
- **discuss** the causes of acid rain and its effects on the environment 12.8

Individual pathways

ACTIVITY 12.1
Revising chemical changes
doc-10573

ACTIVITY 12.2
Investigating chemical changes
doc-10574

ACTIVITY 12.3
Investigating chemical changes further
doc-10575

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FOCUS ACTIVITY

online only

Imagine that you live near a factory or power station that is producing acidic gases and causing harm to the environment. You wish to be elected to the local government board to stop this problem. Write a speech that you could give at an election meeting to clarify the issue.

Access more details about focus activities for this topic in the Resources tab (doc-10572).

12.9 Review 1: Looking back

assessON

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. **Identify** each of the following as either a chemical or a physical change.
   (a) The wax on a burning candle melts.
   (b) The wax vapour at the top of candle wick burns with oxygen to produce carbon dioxide, water vapour and heat.
   (c) Calcium carbonate is dissolved by hydrochloric acid to form calcium chloride, water and carbon dioxide gas.
   (d) Hydrogen gas explodes with oxygen gas to form water.
2. Write word equations for each of the chemical changes in question 1.
3. **Explain** how you know that:
   (a) toasting bread is not a physical change
   (b) rusting of a nail is not a physical change.
4. Some chemical reactions can be useful. **Recall** three examples of useful chemical reactions.
5. Catalysts are sometimes added to the reactants taking part in a chemical reaction.
   (a) **Define** the term 'catalyst'.
   (b) When a word equation is written to describe a chemical reaction, catalysts are not included as either reactants or products. **Explain** why.
6. Rusting is an example of a slow chemical reaction.
   (a) **Recall** the three reactants of rusting.
   (b) **Identify** the product of the rusting reaction.
7. For each of the following reactions, **propose** methods to make the reaction happen more quickly.
   (a) Burning a pile of dry leaves
   (b) Cooking potatoes
   (c) Dissolving marble chips in acid
   (d) Removing a stain using bleach
   (e) Making an iron nail go rusty
   (f) Letting milk go sour
8. Just as chemicals can be grouped or classified, so can chemical reactions. **Recall** the names given to the following two groups of chemical reactions.
   (a) Reactions of metals with oxygen
   (b) Reactions of acids with bases
9. Imagine that you are given a safe, but unknown, liquid and are asked to decide if it is an acid, a base or neutral. You are provided with an acid–base indicator that is safe to use, but it does not have a label on it. You don't know what the colour changes to the indicator mean.
   Outline a step-by-step procedure to describe how you could find out whether the substance is an acid, a base or neutral. You are permitted to use common substances found in just about any kitchen.

10. Each of the four photographs below (a, b, c, d) shows a chemical reaction taking place. **Compare** these chemical reactions.

(a)



(b)



(c)



(d)



11. Some chemicals react as soon as they come into contact with each other. Others need a trigger to get them started. **Identify** two things that can trigger a combustion reaction.

12. The setting of concrete is a chemical reaction that takes place between concrete and water. It is a very slow reaction. Give at least two reasons why scientists may be asked to find ways to speed up the reaction.





13. The oxyacetylene torch shown above is used to melt metals to allow them to be joined together.
    (a) **Identify** what type of chemical reaction takes place in the oxyacetylene torch.
    (b) What evidence is there in the photo that may help you **justify** your answer to part (a)?
14. Many dentists believe that the increase in cavities in young adults is due to the increased consumption of soft drinks at a younger age. They theorise that a chemical reaction takes place between the tooth enamel and the acid in the soft drink.
    (a) **Recall** what acid is found in soft drinks.
    (b) **Design** an experiment that will allow you to investigate the effects of the soft-drink acid on teeth. (*Hint:* Find out what material(s) teeth are made from.)
15. **Identify** which of the following are displacement reactions and which are synthesis reactions.
    (a) magnesium + oxygen → magnesium oxide
    (b) iron + copper sulfate → copper + iron sulfate
    (c) potassium chloride → potassium + chlorine
    (d) ethane + oxygen → carbon dioxide + water
    (e) lead nitrate + potassium iodide → potassium nitrate + lead iodide

Test yourself

1. Which one of the following would you describe as a chemical change?
   (A) Ice-cream melting in the sun
   (B) A match burning
   (C) Breaking an egg
   (D) Boiling water for a cup of tea **(1 mark)**
2. Which of the following is *not* a reaction with oxygen as one of the reactants?
   (A) Combustion
   (B) Oxidation
   (C) Rusting
   (D) Neutralisation **(1 mark)**
3. Which substance is used to coat iron in the process of galvanisation?
   (A) Gallium
   (B) Zinc
   (C) Paint
   (D) Salt **(1 mark)**

4. Consider this word equation for a chemical reaction:

magnesium + hydrochloric acid → magnesium chloride + hydrogen gas

The reactants in this equation are
(A) magnesium and hydrogen gas.
(B) magnesium chloride and hydrogen gas.
(C) magnesium and hydrochloric acid.
(D) magnesium, hydrochloric acid, magnesium chloride and hydrogen gas. **(1 mark)**

5. Have you ever noticed how things made of silver, such as expensive cutlery, old tea services and even jewellery, get a black film over them if they are not used often? That black film, called silver tarnish, is a form of corrosion that occurs when sulfur in the air reacts with the silver metal forming a blackish layer of silver sulfide. You can see the same thing happening much faster if you use a silver teaspoon to eat an egg at breakfast – the sulfur from the egg yolk comes into direct contact with the silver and tarnish forms on the teaspoon in a matter of minutes.

The good thing is that you can use a bit of knowledge about chemical reactions to remove the tarnish. One of the easier methods of cleaning tarnished silver is to wrap a sheet of aluminium foil loosely around the object and then place it in a tub of warm water that has had bicarbonate of soda (sodium bicarbonate) dissolved in it. It is important that the aluminium foil is completely covered by the warm water and that the warm water can get inside the foil. Over time, aluminium from the foil reacts with the silver sulfide of the tarnish to form aluminium sulfide and silver (which remains on your object).

silver sulfide + aluminium → aluminium sulfide + silver

This reaction can take anywhere between a few minutes and a few hours depending on the size of your silver object and how much tarnish there is to remove. When the tarnish has all gone, the silver object is rinsed in clean water to remove any aluminium sulfide.

(a) **Explain** why hot water rather than cold water is used in this method of cleaning silver. Use your knowledge of particle theory to support your answer. **(1 mark)**
(b) Draw a labelled scientific diagram of the set-up for cleaning silver. **(1 mark)**
(c) Does this method work if you use copper foil rather than aluminium foil? Design an experiment that will allow you to find out. **(2 marks)**
(d) This method normally takes a few hours to work. **Describe** at least two methods you could use to make this process happen faster. Use examples you have encountered in your study so far to **justify** why you think these methods would work. **(2 marks)**

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Complete this digital doc: Worksheet 12.8: Chemical reactions puzzles (doc-12456)

Complete this digital doc: Worksheet 12.9: Chemical reactions summary (doc-12457)

TOPIC 13
Growing and multiplying

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?

In the time that it takes you to read this paragraph, hundreds of babies will have been born around the world. How many animals will have been born, how many plants will have germinated and how many new cells will have been produced? In this chapter you will learn about different ways that living organisms reproduce, from bacteria and other unicellular organisms to larger more complex living things. You will also learn about flowering plants and their life cycle, and you will investigate some of the factors that affect the growth of plants.

LEARNING SEQUENCE

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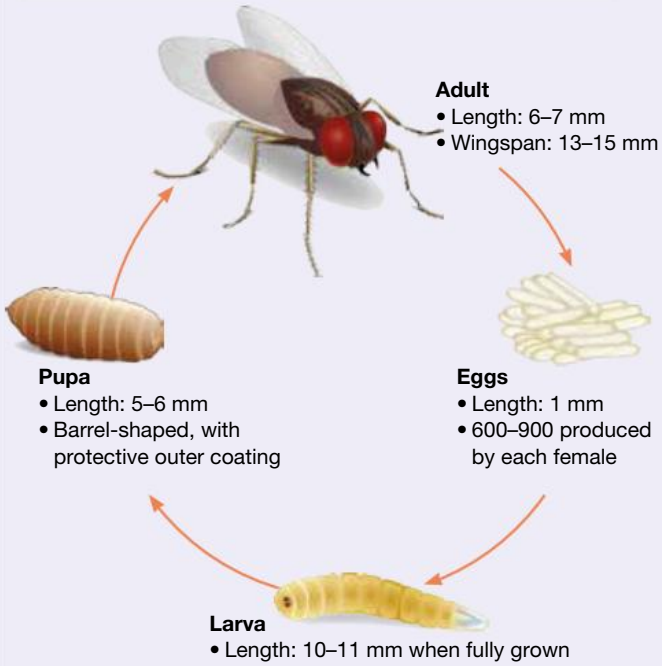
Bees visit flowers to collect nectar. As they do this, they also transfer pollen from one flower to another. This process, called pollination, is an essential step in the life cycle of flowering plants.



Thinking about growing and multiplying

1. The diagram below represents the life cycle of a fly.

Life cycle of a fly



(a) Why is this called a cycle?
(b) The diagram above shows only some of the steps in the life cycle. Mating is not shown. Where would it fit in this diagram?
(c) The larva and pupa look similar. Using only the information in the diagram, outline some of the differences between a larva and a pupa.
(d) Butterflies have a similar life cycle to flies. Match the following stages of the butterfly life cycle with stages of the fly life cycle.
(i) Caterpillar
(ii) Cocoon
(iii) Butterfly
(e) Using the life cycle above, distinguish between growth and development.

2. The diagrams below show some of the stages of the life cycle of a flowering plant and a description of the stages.

Diagram	Description
(a) 	A If the flower has been pollinated, it will develop into a fruit. The fruit contains seeds.
(b) 	B The plant is fully grown.
(c) 	C The seedling grows.
(d) 	D Under the right conditions, the seeds may germinate.
(e) 	E The plant produces flowers.

(a) Use a dictionary to find out the meanings of the terms ‘germination’ and ‘pollination’.
(b) Match each stage with its description.
(c) Organise the stages in the correct order.
(d) Does it matter which step is first? Explain your answer.
(e) The diagrams above show only some of the stages of the life cycle of flowering plants. Where would the pollination fit?
(f) You can grow flowering plants from seeds. What are some other ways that you can produce new plants from existing plants?
(g) A fully grown plant is made up of many more cells than a seedling. Suggest where the additional cells come from.
(h) Apart from growth, what are some other reasons why plants may need to produce new cells?

3. Construct a diagram to represent the life cycle of a frog. Use the internet to locate suitable pictures to illustrate your diagram.

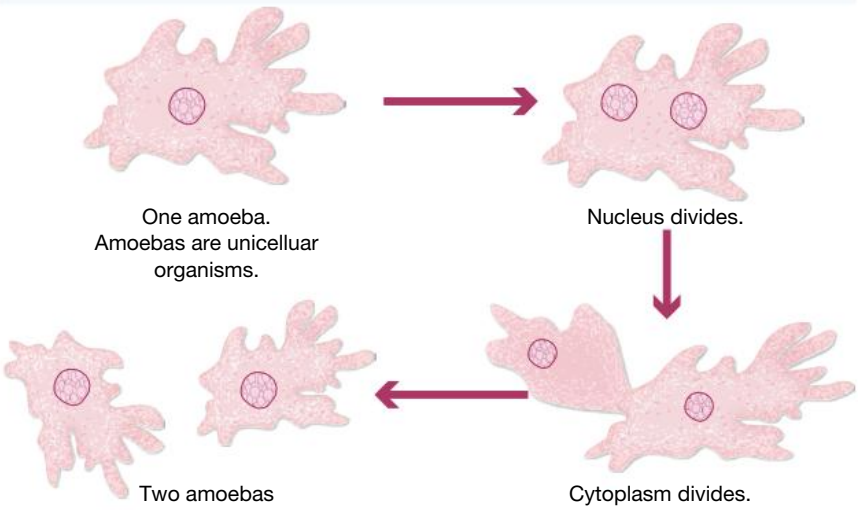
13.2 Multiplying by dividing

13.2.1 Why do cells need to replicate?

As you sit reading this page, new cells are being produced in various locations in your body. These cells will be used for growth and repair or may replace other cells that have died. Cell division is also important in reproduction.

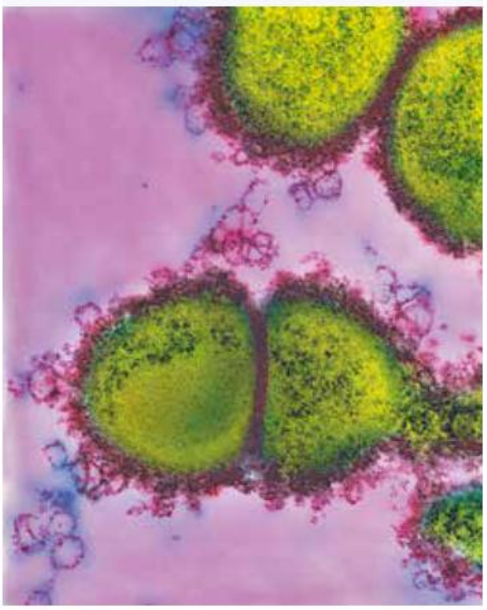
You started out as just one cell: a **fertilised** egg or zygote. Look at you now! That one cell has divided many times to produce all the cells that make up your body. Cells need to be small so that substances can move in and out of them efficiently, so large organisms grow by making more cells. When a fertilised egg begins to divide, all the cells initially have a similar appearance and work in the same way. They are **unspecialised**. After a number of cell divisions, the cells begin to **differentiate**. Some of the cells change and become specialised for particular jobs.

Unicellular organisms reproduce simply by dividing into two cells. This is called binary fission.



Cell division is also needed to replace cells. Each time you dry your skin with a towel, you shed skin cells. To replace these you need to make more skin cells. Similarly, the cells lining your gut need to be replaced frequently. Red blood cells have a life span of approximately 4 months, although they do not divide to make new red blood cells. New red blood cells are made from cells in the bone marrow. Other cells, including nerve cells have a longer life span, although most nerve cells cannot replicate.

Streptococcus pyogenes bacteria, carried harmlessly by many people in their nose or throat. The bacterium at lower centre is dividing into two cells by binary fission.



13.2.2 Unicellular organisms multiply by dividing

Many bacteria and other unicellular organisms reproduce by binary fission. They grow until they reach a certain size, and then the cell divides into two. The genetic material in the cell replicates first, and then the cytoplasm divides. In some instances, the parent cell splits into more than one cell. This is called multiple fission.

13.2.3 Mitosis

Mitosis is the type of cell division that produces the cells needed for growth and repair in multicellular organisms. It is also the type of cell division involved in asexual reproduction in plants and some animals. In these organisms, the genetic material is contained in the nucleus of the cell in the form of chromosomes. Mitosis produces two cells with the same number and type of chromosomes as the parent cell. In flowering

plants, mitosis occurs only in certain parts of the plant, including the tips of the roots and shoots. 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. The cells of a human embryo go through mitosis many times to produce all the cells of an adult human.

The diagram at right shows the process of mitosis. To simplify the diagram, only two pairs of chromosomes are shown, but human cells actually have 23 pairs of chromosomes.

After mitosis has occurred the cell membrane pinches in so that the cell divides into two. This process is known as cytokinesis.

13.2.4 Asexual reproduction

Mitosis is also involved in asexual reproduction. In this type of reproduction, a single parent produces one or more genetically identical offspring. Some examples of asexual reproduction from the animal kingdom include budding, and fragmentation and regeneration.

Budding

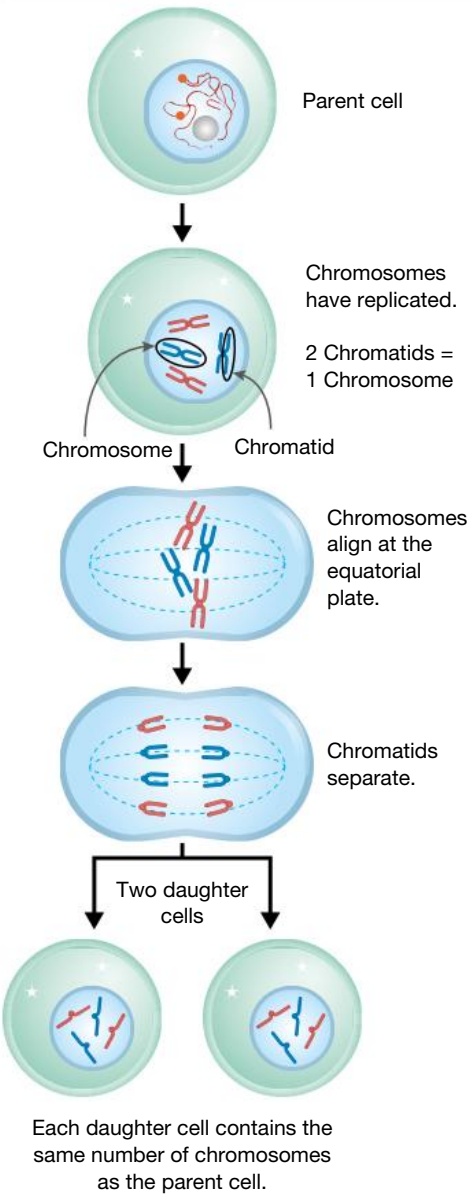
Budding occurs in animals such as jellyfish. It involves the offspring initially forming as a growth on the parent. When the 'bud' is capable of catching its own food, it breaks away and becomes an independent animal. Imagine looking down one day and seeing a miniature baby growing off your arm!

The reproduction process for jellyfish actually starts sexually. Jellyfish are nearly always either male or female. The **sperm** and eggs produced by a group of jellyfish form tiny, 'hairy' larvae, which settle down on a firm surface. There,

Tiny new jellyfish (medusae) that have formed by budding



Mitosis



Each daughter cell contains the same number of chromosomes as the parent cell.

each larva changes into a tiny, tentacle-fringed cup shape, called a scyphistoma. It is the scyphistoma that buds, producing tiny new jellyfish called medusae.

Fragmentation and regeneration

Fragmentation is commonly seen in the flatworm. The adult, or parent, worm breaks up into several pieces, each of which develops into an adult worm over time. Each offspring is identical to the parent worm. This process is similar to regeneration in starfish. If a starfish loses a limb, new limbs will regenerate slowly. In some species of starfish — such as the Linckia starfish commonly found around Hawaii — severed arms can regenerate into completely new animals.

There are many examples of asexual reproduction in plants. Many plants can reproduce both sexually (two parents) and asexually (one parent). Reproducing from seeds is a type of sexual reproduction but producing new plants from cuttings and bulbs or by sending out runners are all types of asexual reproduction.

Tiny new starfish growing at the end of a discarded Linckia starfish arm



Grasses can colonise an area rapidly by sending out runners.



INVESTIGATION 13.1

Mitosis under the microscope

AIM: To observe cells in various stages of mitosis

You will need:

prepared slides of onion root tips (or other prepared slides showing plant or animal cells in various stages of mitosis)
microscope
digital eyepiece (optional)

- Place the microscope slide on the stage of the microscope.
- Focus the microscope carefully to avoid breaking the slide (revise the instructions on page 48 if necessary).
- In many of the cells the chromosomes are not distinguishable. Between divisions, the DNA exists as long strands and does not have a specific shape. Early in mitosis, the DNA coils up into distinct chromosomes. On the slide you are observing, find cells where the DNA:
  – is not in the form of chromosomes
  – has coiled up into distinct chromosomes.

Prophase: the DNA has coiled up and the chromosomes are visible.



Anaphase: the chromatids separate and move towards opposite ends of the cell.



Metaphase: the chromosomes line up in the middle of the cell.



Telophase: the chromatids are now in two separate groups and a new nuclear membrane begins to form around each group.



If you have a digital eyepiece available take photos of the cells and label your photos; otherwise draw a diagram of the cells you identified.

- The photos on the previous page show plant cells at various stages of mitosis. Try to locate a cell in each of these stages on the slide you are observing. Note that the colour of the chromosomes may be different depending on the stain that has been applied to the slide.
- Photograph or draw the cells you identified.

Discussion

1. Why were slides of onion root tip rather than another part of the onion plant used for this investigation?
2. The prepared slides have a stain added. The stain is taken up by the DNA in the cells. Explain why the stain is necessary to observe the stages of mitosis.
3. Use the **Animations of mitosis** weblink in the Resources tab to explain why an animation provides more information about mitosis than the images shown opposite.

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. Match each of the terms below with its meaning.

Term	Meaning
(a) Zygote	A Has a particular structure suited to its function
(b) Specialised	B Found in the nucleus of cells; contains the genetic material of the cell
(c) Binary fission	C Process that occurs after mitosis where the cytoplasm of the cell splits in two
(d) Chromosome	D Fertilised egg
(e) Cytokinesis	E Reproductive process where the parent breaks into pieces and each piece develops into a separate organism
(f) Differentiation	F How bacteria reproduce
(g) Budding	G Process where cells become specialised
(h) Fragmentation	H A type of reproduction where the offspring starts out as a growth on the parent

2. **Distinguish** between sexual and asexual reproduction.
3. **Outline** why cells need to replicate.
4. **Distinguish** between chromatids and chromosomes.

Investigate

5. (a) Place a carrot top on moist cotton wool until leaves appear; then transfer the plant to a plastic pot containing moist potting mix. Record what happens.
   (b) Try this with a variety of other vegetables. **Summarise** your findings.
6. Use the **Animation of mitosis** weblink in the Resources tab and the diagram on the previous page to create a cartoon strip that **summarises** the process of mitosis.

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Explore more with this weblink: Animations of mitosis

Complete this digital doc: Worksheet 13.1: Asexual reproduction (doc-12499)

Complete this digital doc: Worksheet 13.2: Mitosis (doc-12500)

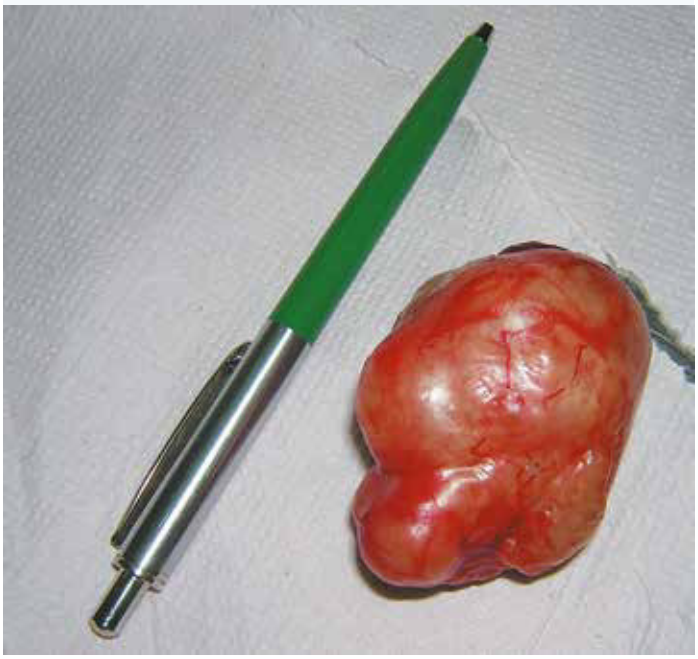
13.3 Out of control!

13.3.1 What is cancer?

In a healthy organism, cells need to divide to enable growth and repair. The process is carefully controlled but what happens when the control mechanisms fail? Cancer is one of the consequences of cells replicating out of control. Finding new strategies to prevent and treat cancer is one way that scientific knowledge is helping to address health issues.

By the age of 85, one in two men and one in three women will have been diagnosed with cancer. Cancer occurs when cells begin to replicate out of control. Under normal conditions the cell cycle is carefully regulated. Certain bits of DNA (genes) regulate when cells grow, divide and die. Damage to the DNA of cells can interfere with this process. Instead of dying, cells can continue to multiply unchecked and form a lump of cells called a tumour. The cells in a tumour are usually undifferentiated — they do not take on the special structure of the cells in that area of the body — so the tumour can interfere with the normal functioning of the organ.

This tumour was removed from a dog's digestive system.



Some tumours grow slowly and do not spread. These are usually considered benign. Provided they do not impact significantly on surrounding tissue, they may be left inside the body and monitored. Malignant tumours are more dangerous because they can spread throughout the body. Fragments of the tumour can break off and travel through the body via the bloodstream or lymphatic system, giving rise to new cancerous masses in other parts of the body.

13.3.2 The role of scientific research

While cancers are still currently the leading causes of death in Australia, knowledge of the disease can play an important part in reducing its incidence and improving survival rates. Scientific research has assisted in the battle against cancer in several ways.

Safety gear is required when handling asbestos.



Identifying carcinogens

Identifying substances (carcinogens) that damage the DNA of cells and cause cancer can help us avoid these. Some of the chemicals in tobacco smoke have been shown to cause cancer, and cigarette packets now carry health warnings. Asbestos, a common building material prior to the 1980s, has been

shown to cause lung cancer. Asbestos is a material that forms fibres; when these become loose they can be inhaled. The use of asbestos in construction has been completely banned in Australia since 2003 and safety protocols, such as wearing appropriate protective clothing and masks, have been developed for workers who handle asbestos in older buildings.

13.3.3 Identifying the role of viruses

There is increasing evidence of the role of viral infections in some types of cancer. Cervical cancer affects the cervix, the passageway between the vagina and the uterus in women. During pregnancy the cervix is closed, but during childbirth it opens up (dilates) to allow the baby to come out of the uterus. Women who contract a virus called the human papillomavirus (HPV) are at higher risk of developing cervical cancer later in life. Most women who contract HPV have no symptoms and cancer may not develop until many years later. As the cancer spreads it may cause symptoms such as unusual vaginal bleeding or discharge, and lower back or leg pain. When the cancer is discovered in its later stages, it is sometimes necessary to remove some of the patient's reproductive organs so that she may no longer have children. The cancer may eventually spread to other parts of the body and cause death. Early detection of cervical cancer greatly increases the chance that a woman will make a full recovery. A pap smear is a medical procedure that can detect cervical cancer in its early stages. It involves scraping cells from the cervix and examining them to check for any abnormalities. It is recommended that women have a pap smear every two years.

Since many of the cases of cervical cancer are linked to HPV infection, protection against HPV is a highly effective way of reducing the incidence of cervical cancer. HPV spreads by sexual contact. While men do not get cervical cancer, they can carry HPV and pass it on to their sexual partners. Professor Ian Frazer, an Australian scientist, recently succeeded in developing a vaccine against HPV. The vaccine, called Gardasil, has the potential to greatly cut down the rate of cervical cancer and save many lives. It is best to be vaccinated when you are young, before you have had a chance to become infected by HPV. For this reason, the Australian government is funding the cervical cancer vaccine for women aged 16 to 26. Different types of HPV can cause cervical cancer and the vaccine protects against about 80 per cent of these; therefore, women who have been vaccinated should still have pap smears.

Australian immunologist Professor Ian Frazer developed Gardasil, a cervical cancer vaccine, which is an Australian invention that can protect against the virus that causes cervical cancer.



13.3.4 Limiting exposure to radiation

There was a time when a visit to the shoe store might have involved having your feet X-rayed inside the shoes to see how much growing room was left. We now know that many types of radiation, including X-rays, can damage the DNA of cells and thus cause cancer. The effect is cumulative; the greater the dose of X-rays you are exposed to over your lifetime, the greater the risk. These days, X-rays are reserved mainly for medical applications, and health professionals take steps to minimise their and the patient's exposure. A lead apron may be used to shield parts of the body that do not need to be X-rayed, and the radiologist usually leaves the room or stays behind a shield while the radiation is being emitted.

UV radiation from the sun also causes cancer. Skin cancer is the most common form of cancer in Australia. In fact, two out of three Australians are likely to get skin cancer at some time during their lives. The most serious forms of skin cancer are responsible for about 1000 deaths each year in Australia. The main cause of skin cancer is exposure to the sun. Ultraviolet radiation reaching Earth from the sun is not

visible. It causes sunburn and is at its peak in the middle of the day when the sun is directly overhead. Ultraviolet radiation can cause cancer in the cells of the epidermis, the top layer of the skin, because it damages the cells' genetic material (DNA).

13.3.5 The three main types of skin cancer

Squamous cell carcinoma



- less common and more dangerous than basal cell carcinoma
- appears as a red, scaly sore
- usually found on the hands, forearms, face and neck, but can spread to other parts of the body
- mostly affects people over 40 who have been exposed to the sun for many years
- kills about 200 Australians each year

Basal cell carcinoma



- most common form of skin cancer and also the least dangerous
- appears as a red, flaky lump on the skin
- rarely spreads to other parts of the body but needs to be treated before it grows large or forms a deep sore

Melanoma



- least common but most dangerous form of skin cancer
- first sign is a change in size, shape or colour of a freckle or mole, or the appearance of a new spot on normal skin
- can spread quickly to other parts of the body
- most common in adults aged between 30 and 50 years, usually caused by long periods of exposure to the sun during childhood and adolescence
- cause of the most deaths from skin cancer — about 800 each year in Australia

Increased knowledge of the risks of sun exposure has resulted in information campaigns aimed at changing people's behaviour. Here are some simple steps that can reduce your risk of skin cancer:

- Avoid going out in the sun in the middle of the day (11 am–3 pm), particularly in summer.
- Wear a shirt with sleeves and a hat when outside.
- Wear a broad spectrum sunscreen labelled 30+ or higher.
- The key to curing skin cancer is early detection. Even melanomas can be cured in more than 95 per cent of patients if they are detected quickly. If you see a new lump or spot, or a changing freckle or mole, see a doctor promptly.

13.3.6 Some questions about fun in the sun

Q: Is a suntan healthy?

A: No. A suntan is evidence that you have been exposed to the sun for too long. A suntan will not protect you from skin cancer. Fake suntan lotions do not offer protection from skin cancer either.

Q: Do I need to worry about sunburn or skin cancer when it's cloudy?

A: Yes. Although clouds block out a lot of the sun's visible light, they do not block out enough ultraviolet radiation to protect your skin completely, especially during summer. The graphs opposite show that light cloud cover has little effect on the harmful ultraviolet radiation reaching the ground on a summer's day in Sydney. Heavy cloud, however, decreases the amount of ultraviolet radiation reaching the ground by over 90 per cent.

Q: Do I need to use sunscreen when I wear a hat?

A: Yes. The sun's radiation is reflected from the ground and from water. Snow and sand reflect a lot of radiation, even on cloudy days. In addition, many hats, including baseball hats, do not protect you from direct radiation. Wide-brimmed hats or 'legionnaire' hats provide the best protection because they shade the neck and ears.

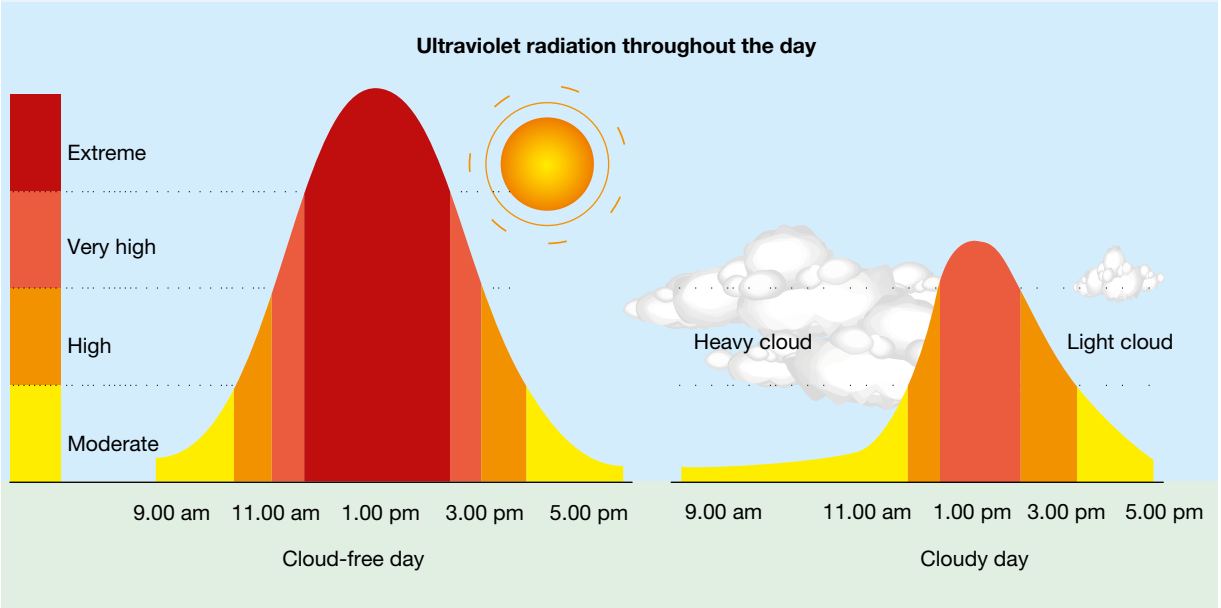
Q: What does SPF 30+ mean?

A: SPF stands for 'sun protection factor.' It allows you to estimate how long you can stay in the sun before your skin starts to go red. This period can be estimated by multiplying the amount of time that it takes your skin to redden by the SPF factor. For example, if your unprotected skin starts to burn after 10 minutes in the hot sun, proper use of SPF 4 sunscreen would allow you to remain in the sun for $10 \times 4 = 40$ minutes before burning starts. After that 40 minutes, you would burn, even with more sunscreen applied. An SPF water-resistant 30+ sunscreen reapplied every 2 hours would allow you to remain in the sun for at least $10 \times 30 = 300$ minutes before burning starts. SPF 30+ sunscreen blocks out about 97 per cent of the sun's radiation.

Q: What does 'broad spectrum' mean?

A: The Cancer Council NSW recommends a broad spectrum SPF 30+ sunscreen. Broad spectrum sunscreens offer protection from the three different types of ultraviolet radiation: UVA, UVB and UVC.

These graphs show how the ultraviolet radiation reaching the ground changes on a typical summer day in Sydney.



13.3.7 Developing treatments for cancer

Some traditional treatments for cancer include:

- Surgery to remove the cancerous mass. This can be highly effective when the tumour is localised and its removal does not cause significant damage to surrounding tissues.
- Radiotherapy to kill dividing cancer cells. Radiation can cause cancer, but it can also be used to treat cancer by killing dividing cells, including cancer cells. Unfortunately, healthy dividing cells are also damaged in the process, causing side effects including nausea, a weakened immune system and often hair loss.
- Chemotherapy to attack cancer cells. Chemotherapy involves taking medication that kills cancer cells. Again, some healthy cells are also killed by the drugs resulting in unpleasant side effects.

Finding new treatments for cancer that target cancer cells specifically and have few side effects is an important goal for science. Here are just a few recent discoveries in the area of cancer research.

- An Australian drug company called Peplin has developed a gel, made from a common weed called *Euphorbia peplus*, which has been used successfully to treat some skin cancers. The plant contains a cancer-fighting chemical. Peplin has found a way of extracting this chemical from the plant and making it into a gel that can be applied to skin cancers. When the gel was tested, it cleared most skin lesions after just two days.
- A company in the US is investigating the use of scorpion venom in cancer treatment. The venom of the deathstalker scorpion contains a substance called chlorotoxin, which sticks to tumour cells but not healthy cells. It may be possible to combine chlorotoxin with chemicals that emit cancer-destroying radiation. Since the chlorotoxin sticks to the cancer cells, the radiation emitting chemicals could be delivered exactly where they are needed. Another possible use for chlorotoxin is to use it to make 'tumour paint'. The chlorotoxin is tagged with a fluorescent paint so that the cancer cells it sticks to can be more easily identified and removed by a surgeon.
- New ways of delivering cancer-fighting drugs are being investigated. Most drugs used for chemotherapy are toxic to rapidly dividing cells, whether they are healthy or not. This limits the dose that can be administered to patients. Packaging the drugs with nanoparticles (very tiny particles) might help target cancer cells more specifically so that higher doses can be administered with fewer side effects. Nanoparticles tend to accumulate in tumours due to differences in the blood vessels that support them.
- Researchers at the University of Canberra have been investigating the benefit of substances extracted from mistletoe to patients undergoing cancer treatment. Mistletoe plants contain compounds that can help the immune system get rid of cancer cells or attack the cancer cells directly. Mistletoe berries contain a toxin that also contributes to the effectiveness of the mistletoe extract. The researchers are looking for the best design and coating for capsules containing mistletoe extract to ensure that the active ingredients are delivered exactly where they are needed. Ideally, the compounds need to be released near the cancer cells and stimulate an immune response localised to that area.

The venom of the deathstalker scorpion contains a substance that sticks to cancer cells but not healthy cells.



Mistletoe



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.

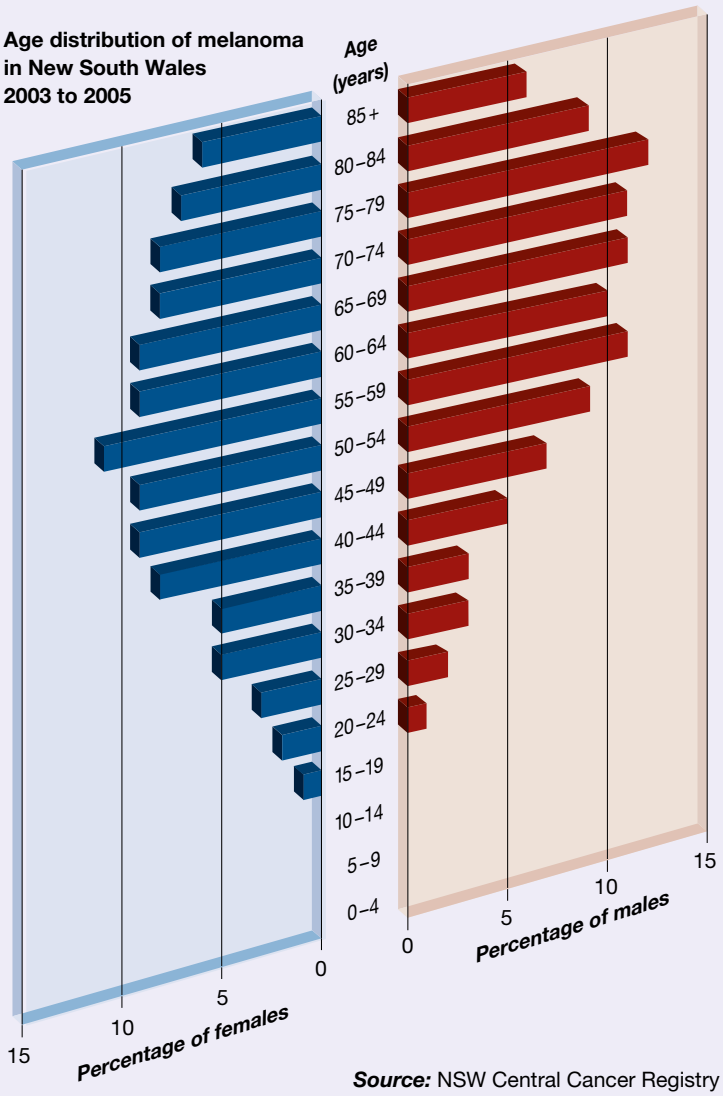
Remember

1. **Outline** why damage to the DNA of cells can cause tumours to form.
2. **Distinguish** between a benign and a malignant tumour.
3. **Recall** two examples of carcinogens.
4. What measures are used to minimise the risks associated with medical X-rays for patients and health professionals?

5. **Distinguish** between chemotherapy and radiotherapy.
6. **Recall** which part of the sun's radiation is the major cause of skin cancer and sunburn.
7. **Identify** the most dangerous time of day to be out in the sun.
8. **Outline** what you should look for on the skin when checking for signs of skin cancer.
9. **Outline** five ways that you can help protect yourself from skin cancer.
10. **Outline** how chlorotoxin might be used in cancer treatment.
11. Why are researchers interested in packaging cancer drugs with nanoparticles?
12. Why are researchers at the University of Canberra investigating a mistletoe extract?

Think

13. **Explain** why it is a good idea to check whether a building contains asbestos before beginning renovations.
14. **Explain** why protecting women from infection with HPV can reduce the risk of cervical cancer.
15. Men do not get cervical cancer, yet it has been proposed that both boys and girls should be immunised against HPV in Year 7. Suggest why immunising boys could reduce the incidence of cervical cancer in years to come.
16. **Explain** why women who have been immunised against HPV should still have regular pap smears.
17. Melanomas occur mostly in adults over the age of 30. **Explain** why it is so important that young children and adolescents are aware of the dangers of the sun's radiation.
18. Daniel has very pale, sensitive skin that begins to burn after only eight minutes in the summer sun. He goes to the beach and takes a tube of SPF 6 sunscreen with him.
    (a) If he doesn't go swimming, **calculate** how long he would be able to sit in the sun before getting burned, assuming that he applies his sunscreen correctly.
    (b) If he used SPF 15+ sunscreen instead, would he be safe sitting in the sun all day? **Justify** your answer.
19. Kimberley is planning to play a game of tennis with a friend on a warm summer's day. What should she take with her to protect her skin from the sun?



Source: NSW Central Cancer Registry

Skill builder

20. In a class of 15 girls and 14 boys, predict the number of boys and girls who will be diagnosed with cancer by the time they reach the age of 85 based on the current incidence of cancer in Australia.

Think and reason

21. **Extract** the answers to the following questions from the graphs above.
    (a) Which age groups of males are most affected by melanoma?
    (b) Which age groups of females are mostly affected by melanoma?
    (c) Does melanoma appear to be more common in males or in females over the age of 50? Why do you think this is the case?

Create and design

22. Design a colourful poster that would encourage people to protect themselves from the sun's harmful radiation.
23. Design and **construct** a multipurpose hat that shades the head and has at least one other purpose. Give your multipurpose hat a name. Prepare an advertising brochure and instruction manual for your hat.

Investigate and design

24. Design and carry out a survey (consisting of a series of questions) to **investigate** whether people of different age groups protect themselves from the danger of skin cancer by wearing hats, shirts and sunscreens. By sharing your data with other members of your class, you may be able to form a sound conclusion.

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Watch this eLesson: A cure? (eles-0070)

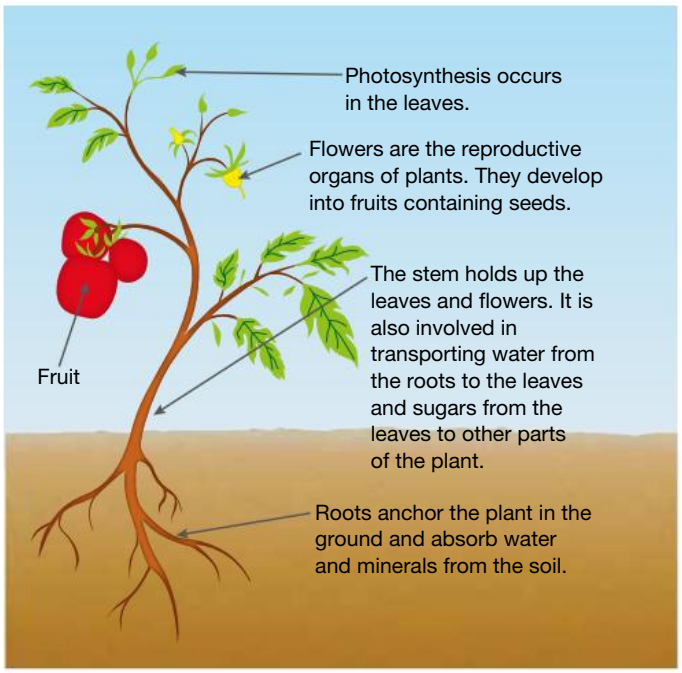
Complete this digital doc: Worksheet 13.3: Skin (doc-12458)

13.4 Plant parts

13.4.1 Hairy roots and all

Plants are multicellular organisms; they are made up of more than one cell. Like other multicellular organisms, they contain organs that work together to keep them alive. The main organs of plants are the roots, stem, leaves and flowers.

Roots both anchor the plant and help it to obtain water from the soil. Plants obtain water and **mineral salts** through their roots. **Root hairs** found on the outermost layer of the smallest roots can greatly assist this process. These are long cells that act like thousands of tiny fingers reaching into the soil for water and soluble salts. For most plants, it is important for their roots to be in soil that is well drained. Plants need **oxygen** for respiration, and the uptake of mineral salts is usually reduced if the roots are waterlogged.



13.4.2 Hold and carry

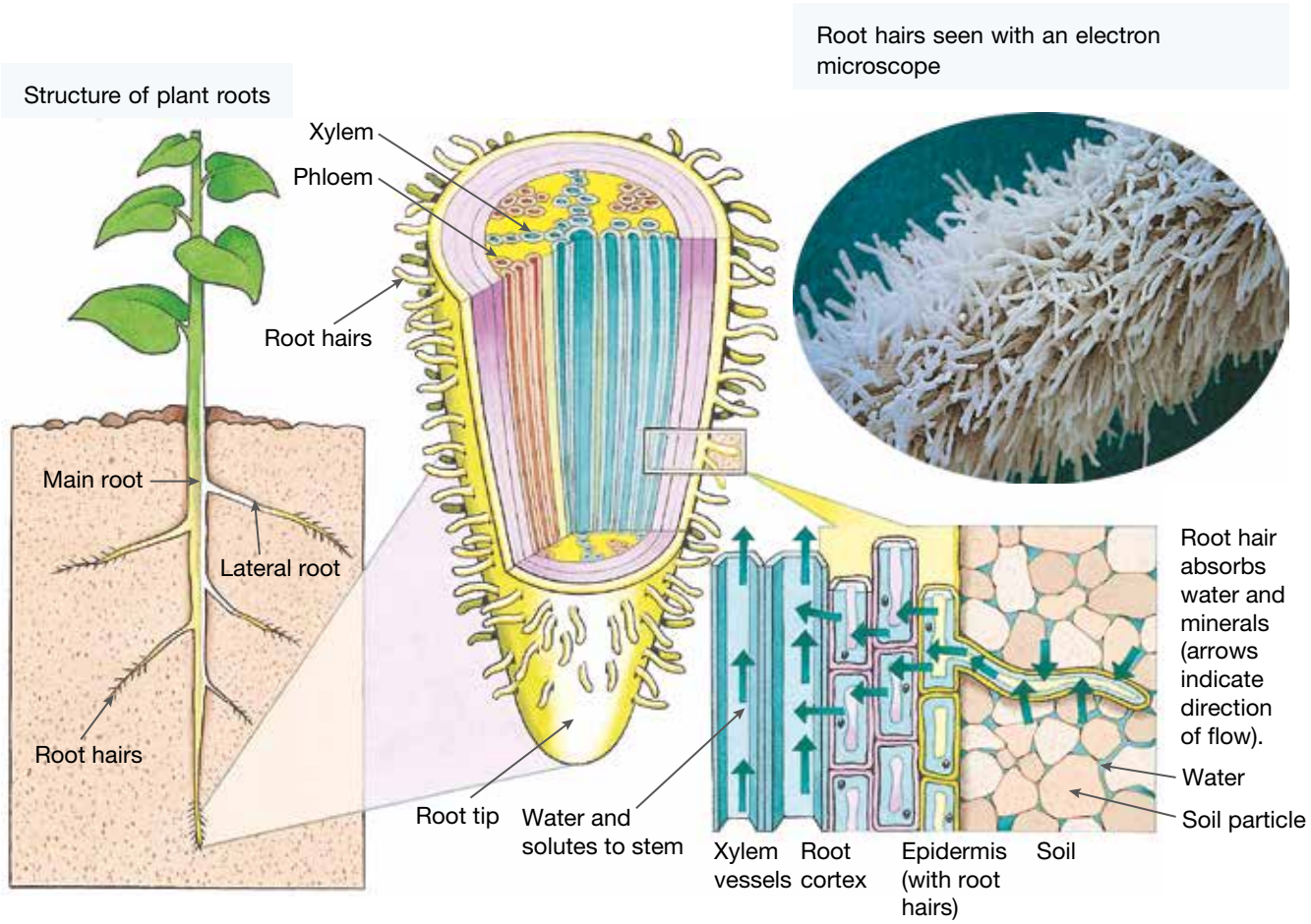
Plant stems serve two important functions; they hold up the leaves and flowers, and they transport substances throughout the plant. Water must travel from the soil up to the leaves, and sugars made in the leaves need to be transported to all parts of the plant.

Conducting tissue: xylem and phloem

The roots, stems and leaves of plants contain **conducting tissue** to transport substances from one part of the plant to another. There are two types of conducting tissue: **xylem** and **phloem**.

Xylem tissue carries water and minerals from the roots of plants to all other parts of the plant. It consists of long hollow tubes made up of the remains of dead cells. The cells that xylem tubes are formed from have their cell walls strengthened with a woody substance called **lignin**. This makes them quite sturdy.

Phloem tissue transports sugars made in the leaves to other parts of the plant. Phloem is made up of two types of cells: sieve cells and companion cells. Sieve cells, like xylem cells, arrange themselves end to end to form long tubes, but the cells that make up sieve tubes are still alive. They are called sieve cells because their cell walls have holes in them (like sieves) at each end of the cells to allow substances to move from one cell to another. Sugars can move both up and down sieve tubes. The movement of sugars throughout the plant is called **translocation**.



13.4.3 Which minerals do plants need?

Animals get the minerals they need from the food they eat. Plants do not eat food. They make the sugars they need for energy by photosynthesis, and they absorb minerals from the soil.

Plants without soil

Hydroponics is a way of growing plants without soil. Hydroponic systems use coarse sand, pebbles or rock-wool to support the plant's roots.

The **nutrients** that plants usually get from the soil are supplied in a water solution. The water solution is trickled over the roots of the plants. This allows the roots to get lots of oxygen and not become water-logged. Vegetables such as lettuces, tomatoes and beans are sometimes grown hydroponically.

Plants in hydroponic systems receive nutrients in a water solution.



The roots of hydroponically grown plants may be supported by pebbles, rockwool or sand.



INVESTIGATION 13.2

Stem transport systems

AIM: To identify xylem tissue in celery

You will need:

celery stick (stem and leaves)
blue food colouring
knife
red food colouring
two 250 mL beakers
hand lens
water

- Slice the celery along the middle to about halfway up the stem.
- Fill two beakers with 250 mL of water. Colour one blue and the other red with the food colouring.
- Place the celery so that each 'side' of the celery is in a separate beaker.
- Leave for 24 hours and then observe the celery.
- Cut the celery stick across the stem.
- Use the hand lens to look at the inside of the stem.







Discussion

1. Look at where the water has travelled in the celery. Draw a diagram to show your observations.
2. Draw a diagram to show what you can see when you cut across the stem.
3. Where is the differently coloured water found in the stem?
4. Where are the different colours found in the leaves?
5. Draw a diagram of the whole celery stick and trace the path of the water through each side to the leaves.
6. How could you turn a white carnation blue? Try it.

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. Copy and complete the table below.

Organ	Function
Roots	
Stem	
Leaves	
Flower	

2. **Outline** why plant roots have small hairs.
3. Copy and complete the table below.

Tissue	What it carries	Direction of movement	Name of cells that form tubes	Are cells that form tubes living?
Xylem				
Phloem				

Think

4. **Classify** the following vegetables as leaf, stem, fruit, flower or root.
   (a) Carrot (b) Celery stick
   (c) Lettuce (d) Potato
   (e) Beans (f) Peas
   (g) Artichoke (h) Capsicum
   (i) Cauliflower (j) Tomato
   (k) Broccoli (l) Onion
5. At the supermarket, some lettuces are labelled ‘hydroponic lettuce’. **Define** what this means.

Investigate

6. Observe a number of different types of roots, using a stereomicroscope, and then record your observations as diagrams.
7. Find out what the main chemicals in fertiliser are.
8. **Design** an experiment to test each of the following hypotheses.
   (a) Bean plants that have fertiliser X added to their soil produce larger beans.
   (b) Rose bushes produce more flowers if fertiliser A is added to the soil they grow in.
   (c) Pine seedlings grow fastest if you add one capful of fertiliser B to every 500 g of potting mix.

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Complete this digital doc: Worksheet 13.4: Roots, stems and leaves (doc-12459)

Complete this digital doc: Worksheet 13.5: Plant transport highways (doc-12460)

13.5 Leafy exchanges

13.5.1 Photosynthesis

Leaves are the main site of photosynthesis in most flowering plants. Their shape and structure ensures that this process is as efficient as possible.

Plants do not need to take in food because they carry out **photosynthesis**. This important process occurs mainly in the leaves of plants. When plants photosynthesise, they use the energy from sunlight to convert carbon dioxide from the air and water taken up from the soil into glucose and oxygen. A green pigment called **chlorophyll** is needed. Photosynthesis consists of a number of steps but it can be summarised by the overall equation below.

$$\text{carbon dioxide + water} \xrightarrow[\text{chlorophyll}]{\text{sunlight}} \text{glucose + oxygen}$$

Most plants have flat, thin leaves to maximise the area exposed to sunlight and their tissues are organised to make photosynthesis more efficient. The outer layer of leaves, the epidermis, is clear to allow light to penetrate to the layers beneath.

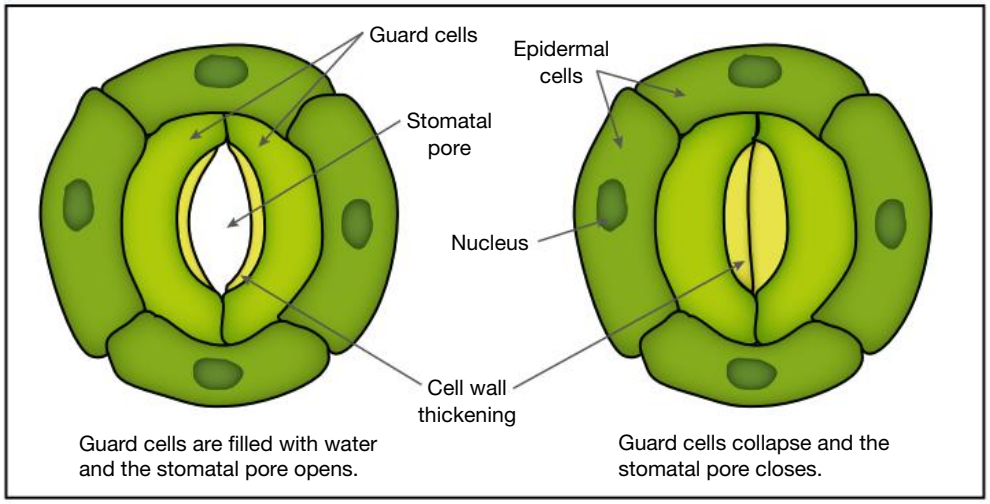
13.5.2 Solar powered

There are small holes in the leaves called stomata (singular = stoma). These small holes allow gases such as carbon dioxide, oxygen and water vapour to move in and out of the leaf. They are located mainly on the underside of leaves. The stomata can be seen clearly under the microscope. They are surrounded by two kidney-shaped cells called **guard cells**. The guard cells can open or close the stomata depending on the plant's need. When the plant has plenty of water, the guard cells fill up with water and stretch lengthways. This opens the pore. If water is in short supply, the guard cells lose water and collapse towards each other to close the pore. This is one way that the plant can control its water loss.

Stomata are surrounded by guard cells on the underside of a leaf.



Stomata can close to conserve water.



HOW ABOUT THAT!

Scientists have used genetic engineering technology to produce plants that glow particular colours when they have mineral deficiencies. This provides farmers with information about which soils need extra minerals added.

INVESTIGATION 13.3

Observing leaf epidermal cells

AIM: To observe leaf epidermis and identify stomates

You will need:

leaf
clear sticky tape
microscope slide
microscope



You can make a 'slide' of leaf epidermal cells with sticky tape.

- Put some sticky tape over a section of the underside of a leaf.
- Press the sticky tape firmly onto the leaf.
- Tear the tape off. Some of the lining cells should come off with the sticky tape.
- Press the tape, sticky side down onto a microscope slide.
- View the sticky tape under the microscope.
- Try to find a pair of guard cells and one of the stomata.

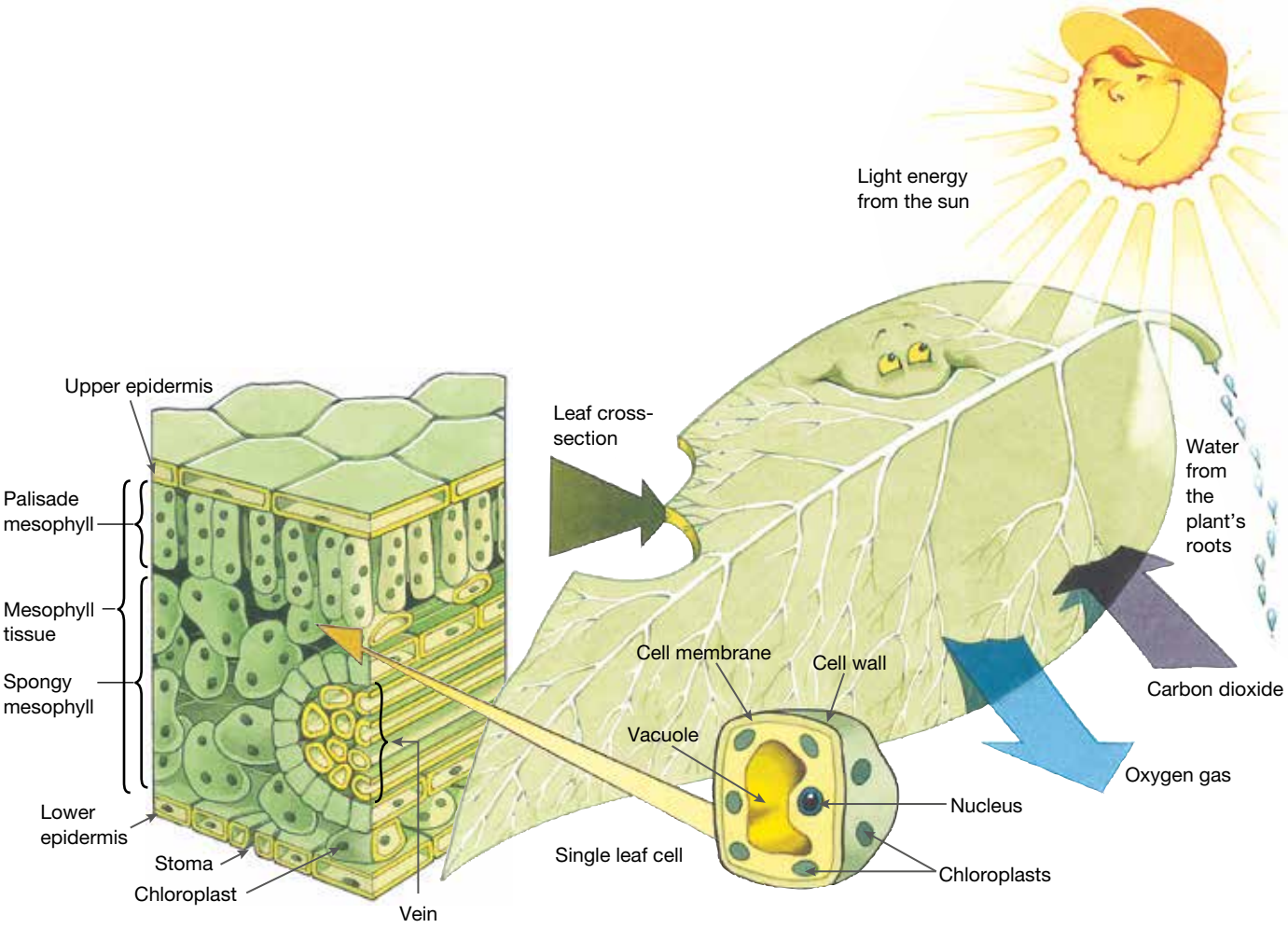
Discussion

1. Is the stoma (the opening) open or closed?
2. Make a drawing of a group of cells, including the guard cells. Include as much detail in your drawing as possible.
3. Label the guard cells and stomata.
4. Title and date your drawing. Write down the magnification used.

13.5.3 Why plants are green

Under the epidermis are the mesophyll cells, where the action happens. They are packed with **chloroplasts**, the green organelles that are the site of photosynthesis. There are two types of mesophyll cells. The layer of cells just under the upper epidermis is called palisade mesophyll because the cells are lined up like the posts in a picket fence (from the French *palissade* meaning 'picket fence'). Below the palisade mesophyll is the spongy mesophyll, so called because it has air pockets. These air pockets are important. Many plants open their stomata for only part of the day. When the sun is strongest they close their stomata to conserve water. The air pockets allow gases to remain inside the leaf when the stomata are closed so that there is a supply of carbon dioxide for photosynthesis for some time after the stomata have closed. Leaves also have veins. These contain xylem and phloem tissue like the stem. Water travels from the stem into the leaves via the veins, and the sugars produced in photosynthesis are transported to other parts of the plant in the phloem.

Leafy exchanges



13.5.4 Investigating photosynthesis

How do we know that plants need carbon dioxide, water and chlorophyll for photosynthesis? What evidence do we have that photosynthesis produces oxygen and glucose? Many scientists have done experiments over many years to gradually reveal all the facts we now have about photosynthesis. The timeline opposite shows some of these experiments.

Discovery journal of photosynthesis

1450

Nicholas of Cusa
German cardinal
(1401–1464)

Proposed idea that weight gained by plants is from water, not soil

Demonstrated that most material in a plant's body does not come from soil; he suggested it comes from water

Jan Baptista van Helmont
Dutch physician
(1577–1644)

1700

1720

Suggested plants get some nourishment from air

Stephen Hales
British physiologist/clergyman
(1677–1761)

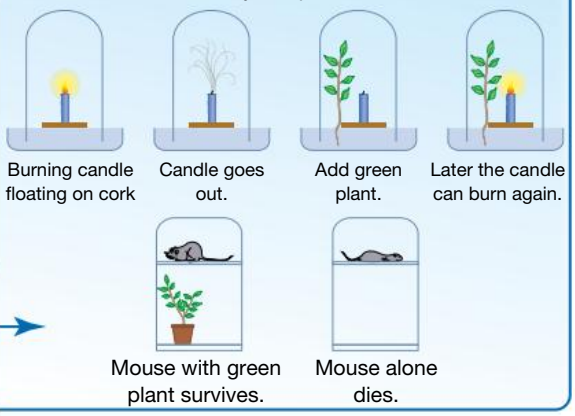
1740

Showed that plants could 'restore' air injured (by respiration)

Joseph Priestley
British chemist/clergyman
(1733–1804)

1760

Priestley's experiment



1780

Showed that plants need sunlight to restore 'injured air' and that only the green parts do this; all parts of plants 'injure' air (i.e. respire)

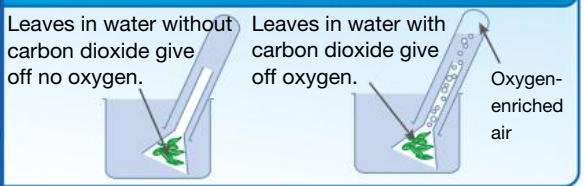
Jan Ingenhousz
Dutch physician
(1730–1799)

1800

Various European chemists (late 18th century)
Oxygen discovered and identified as 'restored' air, carbon dioxide discovered and identified as the 'injured' air

Jean Senebier
Swiss minister (1742–1809)

Demonstrated that plants use carbon dioxide dissolved in water as food



1820



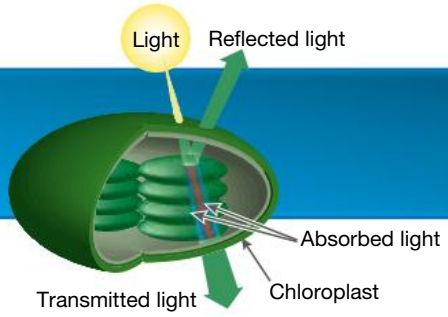
Maize seedling held by the cork, with roots in the culture solution

Julius von Sachs
German botanist
(1832–1897)

1840

Discovered plant respiration, and that chlorophyll is found in chloroplasts; showed that starch grains form during photosynthesis, and that plants take in and use minerals from the soil; showed that minerals were required for making chlorophyll

1860



1880

Theodor Wilhelm Engelmann
German physiologist (1843–1909)
Showed that oxygen was produced by chloroplasts, and that red and blue light are the most important wavelengths for photosynthesis

1900

Sugary sweet — the many journeys of glucose



Plants may use the glucose made by photosynthesis in four main ways:

1. used straight away as energy
2. stored — changed into starch or oil and stored in the stems, roots, seeds and fruits
3. used to make cellulose for the cell walls
4. combined with minerals and used to make proteins and other substances for plant growth.

INVESTIGATION 13.4

Out of the light

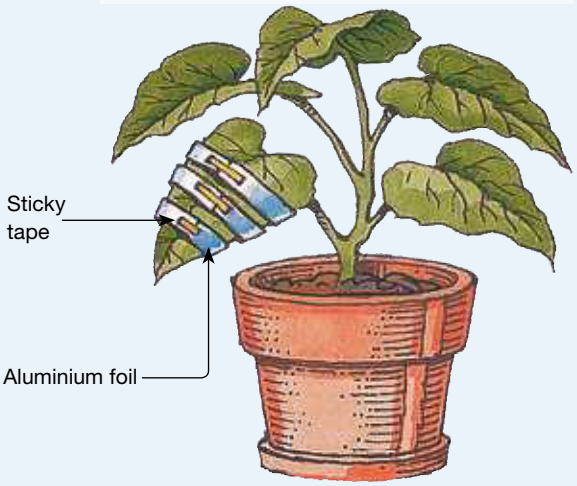
AIM: To determine whether light is needed for photosynthesis

You will need:

pot plant that has been kept in the dark for a few days
several strips of aluminium foil
scissors and sticky tape
hotplate
500 mL beaker of boiling water
test tube of ethanol
forceps
iodine solution and dropping pipette
Petri dish
watchglass with a small sample of potato starch

- Fix aluminium strips to one leaf of a plant as shown in the figure on the right. Make sure that both sides of the leaf are covered by the strip and that you do not damage the leaf.
- Leave the plant in the light for 3 days.
- Remove the leaf from the plant and take off the foil.
- Dip the leaf into boiling water for 10 seconds, and then place it in a test tube of ethanol.

Make sure that the aluminium strips are secured, and that you do not damage the leaf.



CAUTION: Ethanol is flammable. Do not place it near a naked flame. Use a hotplate to heat the water.

- Stand the test tube in the beaker of hot water and leave for 10 minutes. This treatment will remove the chlorophyll.
- While the leaf is in the ethanol, test a small sample of potato starch on a watchglass with the iodine solution. Note any colour change.
- Remove the leaf from the ethanol with the forceps and dip it into the hot water in the beaker again to remove any excess ethanol.
- Place the leaf into a Petri dish and cover with iodine solution. Note any colour change and where on the leaf any such change occurred.

Discussion

1. Glucose is produced during photosynthesis and is then converted to starch and stored. Did your test show any differences in starch production between the sections of leaf exposed to the light and the sections kept in the dark?
2. Which variable was investigated in this experiment?
3. Why was the plant kept in the dark for a few days before the experiment?
4. What inferences (suggested explanations) can you make from your observations?
5. What is the control in this experiment?

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. **Recall** the name of the process by which plants make their own food.
2. **Recall** the word equation for photosynthesis.

Think

3. **Explain** each of the following.
   (a) Leaves have a flat shape.
   (b) The leaves on many trees are attached to branches in such a way that the leaves do not overlap very much.
   (c) Rainforest plants tend to have much larger leaves than desert plants.
   (d) Rainforest plants tend to have more stomata than plants that grow in dry environments.
   (e) Guard cells and stomata are usually found only on the lower part of the leaf, away from direct sunlight.
4. Suggest how guard cells got their name.
5. Would you expect to find chloroplasts in the cells of plant roots? **Explain** your answer.

Skill builder

Refer to the timeline Discovery journal of photosynthesis and answer questions 6–13.

6. If you bought a small plant today and watered it regularly, one year later its mass would have increased. According to Nicholas of Cusa the increase in mass would have come from the water you gave the plant, rather than the soil.
   (a) **Describe** how you could prove that the matter in the soil had not turned into plant matter.
   (b) Was Nicholas of Cusa correct? **Propose** what actually causes the increase in the mass of the plant.
7. Stephen Hales suggested that plants get some nourishment from the air. **Identify** what plants actually need from the air to photosynthesise.
8. Study Priestley's experiment.
   (a) **Propose** why a candle goes out if it is placed in a sealed jar.
   (b) Why was Priestley able to relight the candle after the plant had been growing in the jar for some time?
   (c) Why does a mouse die if left in a sealed jar?
   (d) Why did the mouse survive if it was placed in a sealed jar containing living plants?
   (e) Priestley stated that plants could 'restore injured air'. What do you think he actually meant by that?
9. Jan Ingenhousz's statement could be re-written in the following way.
   Plants need sunlight to produce (a) _____. Only the green parts of plants can produce (b) _____ by (c) p_____. All parts of plants (d) r_____.
10. Which gases were identified as 'restored air' and 'injured air' in the late eighteenth century?
11. **Outline** what the experiment carried out by Jean Senebier revealed about photosynthesis.
12. Look at the diagram next to the name Julius von Sachs. **Identify** which of the discoveries made by von Sachs was probably made using this apparatus.
13. **Identify** the colours of light that are absorbed best by chloroplasts.
14. Why do many rainforest plants have such large leaves?



Investigate

15. View prepared slides of leaf epidermis from different species of plants and find pictures of leaf epidermis from various plants on the internet. Do all epidermal cells have the same shape?
16. Place a plastic bag over the leaves of plants growing in the school grounds. Seal the bag and record the amount of water collected over 24 hours. What conclusions can you draw from your results?

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Complete this digital doc: Worksheet 13.6: Leafy exchanges (doc-12461)

Complete this digital doc: Worksheet 13.7: Photosynthesis (doc-12462)

13.6 The sex life of plants

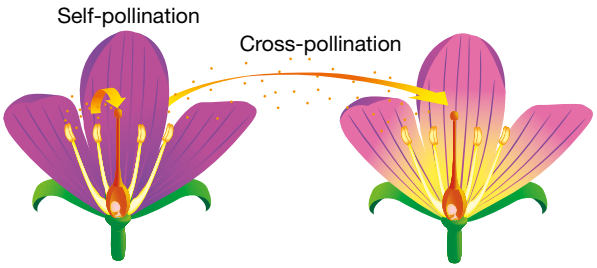
13.6.1 Pollination

Plants can be grown from cuttings, bulbs or runners. They can also be grown from seeds. Producing seeds is an example of sexual reproduction and it all starts with flowers.

Flowers are involved in reproduction. They contain the sex organs of plants. Some flowers contain male sex organs, some contain female sex organs and some contain both! Flowers are designed to increase the chance of pollination, the process where pollen produced by the male parts of flowers lands on the stigma of the female part of a flower.

Pollination describes the way in which pollen grains reach the stigma. Plants may pollinate themselves (**self-pollination**). More often, however, they obtain the pollen from the flower of a different plant of the same species (**cross-pollination**). Cross-pollination increases the variation among the offspring and gives them a better chance of survival. The pollen grains may be transferred to other flowers by wind, insects and other animals.

The difference between self-pollination and cross-pollination



Insect-pollinated flowers usually have attractive, brightly coloured petals and nectaries. The pollen grains themselves may be in a shape that makes them become easily attached to the insect.

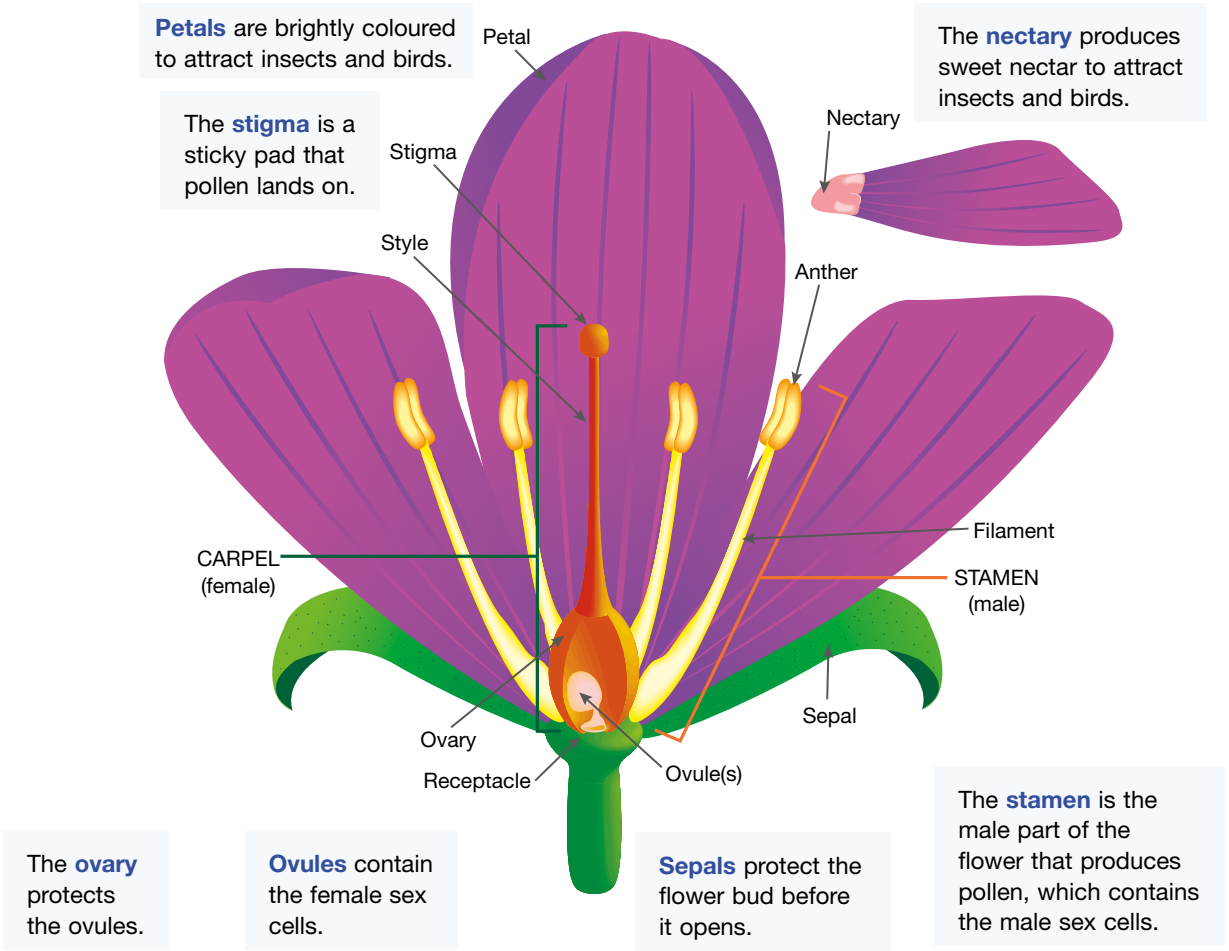
Wind-pollinated flowers are usually less conspicuous and have no large scented petals or nectar. Their shape enables small, light pollen grains to be shaken from the plant and carried away with even the slightest gust of wind. The anthers hang outside the flower and the feathery stigmas spread out to catch airborne pollen grains.

HOW ABOUT THAT!

Some plants are shaped in the form of the sexual partner of an insect, and the plants may secrete chemicals that excite or stimulate the insect. This may increase the contact between the insect and the plant pollen. Some insects are so fooled by these plants that they attempt to mate with them. On occasions, insects even release their own sperm into the flower.

The bee orchid looks and smells like a bee to other bees.





Fertilisation

After pollination comes **fertilisation**. Once the pollen lands on the stigma of a flower, pollen tubes grow down the **style**. The male sex cells travel down the pollen tubes all the way to the ovules inside the ovary where fertilisation occurs. Fertilisation is the fusing of a male sex cell with the female sex cell.

Which do you think is insect pollinated and which is wind pollinated?



INVESTIGATION 13.5

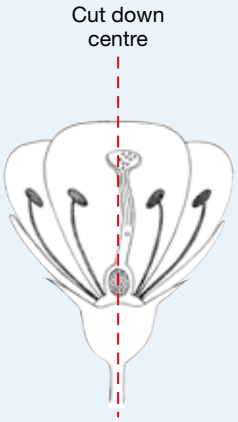
What's in a flower?

AIM: To identify the parts of a flower

You will need:

flowers *cutting board* *tweezers*
sharp knife or razor blade *hand lens*

- Draw a picture of your flower. Locate, count and label the petals and sepals.
- Identify and label the male and female parts you can see.
- Place the flower on the cutting board and hold it with the tweezers.
- Carefully cut the flower in half down the middle (a vertical cross-section).
- Use the hand lens to look at the ovary and ovules.
- Draw the cross-section and label the female parts inside the flower.



Discussion

1. Which parts of the flower become the seeds?
2. Which part of the flower do you think will grow into the fruit?

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. Match the words in the left-hand column below with those in the right-hand column.

Sepal	Sperm
Petal	Sugar
Pollen	Leaflet
Nectary	Colour
Ovule	Egg cell

2. **Propose** why plants usually produce so many pollen grains.
3. **Explain** the difference between pollination and fertilisation.
4. Complete the table below for each of the labelled plant parts in the diagram above.

Flower part	Function	Male, female or neither

Investigate

5. Is there a relationship between the colour of a flower and the strength of its scent? Design and carry out an investigation to determine whether the colour of the flower influences how strong the scent is.
6. Find pictures of examples of wind-pollinated and insect-pollinated flowers.
7. The sunflower, shown above, is actually not a single flower. The 'heart' of the flower consists of hundreds of small flowers close together. The 'petals' are not actually real petals either. They are modified leaves, but they do a great job of attracting insects. This flower organisation enables many flowers to be pollinated at once as insects walk over the 'heart' of the flower to collect nectar.
   (a) **Investigate** which other plants have their flowers organised like the sunflower.
   (b) Are there some other ways that small flowers can be organised to look like one large flower from far away? Find examples.
8. Complete the **Sex life of plants** interactivity in the Resources tab to answer questions about how plants reproduce. Success rewards you with a video of pollination.

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Complete this digital doc: Worksheet 13.8: Plant reproduction (doc-12463)

Try out this interactivity: Sex life of plants (int-0211)

13.7 Plants and parenthood

13.7.1 Eggs, embryos, seeds and fruit

Are you aware that when you bite into an apple, cherry or orange you are actually eating the enlarged ovary of the plant? Did you know that these swollen ovaries contain the plant's 'babies' in their embryonic form? The plants are using you as a way of distributing their 'young' out into the world.

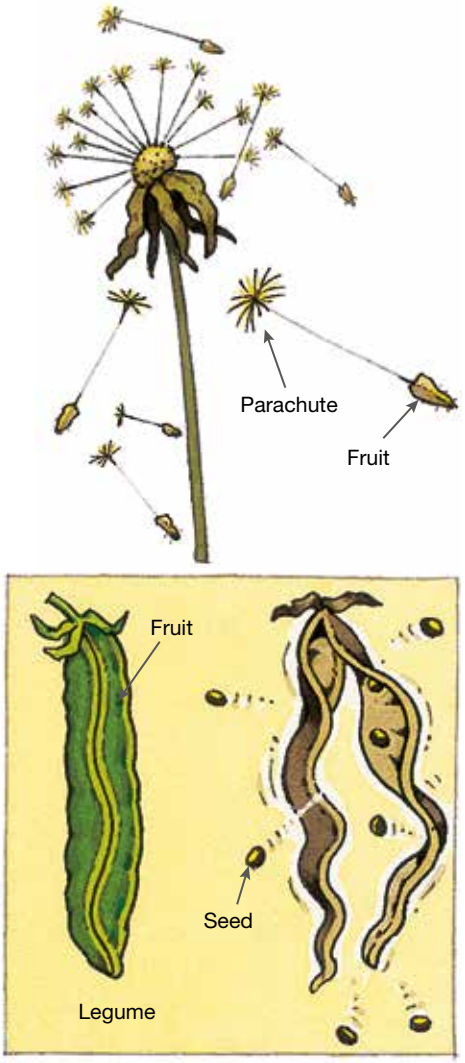
Once the flower has done its job and the egg cell has been fertilised by the pollen nucleus, another sequence of events takes place. The fertilised egg, in the middle of the ovule, divides into a little ball of cells that becomes an **embryo**. Special tissue called **endosperm** surrounds the embryo and supplies it with food.

The ovule becomes the **seed** and tissue forms around it to provide a protective **seed coat**. During the formation of the seed, the ovary expands and turns into a **fruit**.

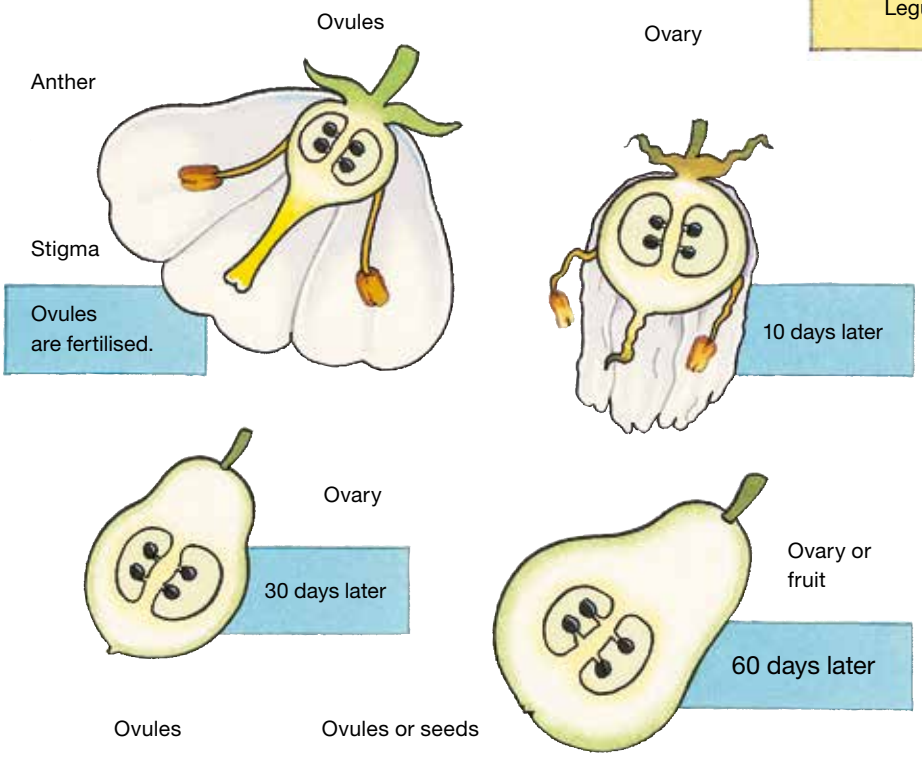
13.7.2 Seed dispersal

One of the main jobs of fruits is to help **disperse** or spread the seeds. There is a variety of ways in which plants disperse their seeds: dispersal may involve animals, including birds (as for tomatoes, grapes and apples); water (as for coconuts); or wind (as for grasses and dandelions). Some plants can disperse their seeds by themselves. For example, the fruits of some plants in the pea family (legumes) split open suddenly when they are ripe and dry, throwing the seeds out for long distances.

Wind dispersal (top) and self dispersal (bottom)



A pear: from flower to fruit

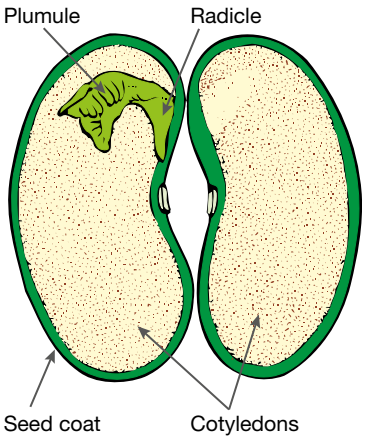


13.7.3 Seeds and germination

The embryo, inside the seed, is made up of three different parts: the baby shoot (**plumule**), the baby root (**radicle**) and one or two thick, wing-like **cotyledons**.

When the conditions are right, the seed bursts open and a new plant grows out. This process is called **germination**. When germination is complete, the embryo has become a young plant or **seedling**.

Parts of a seed before germination



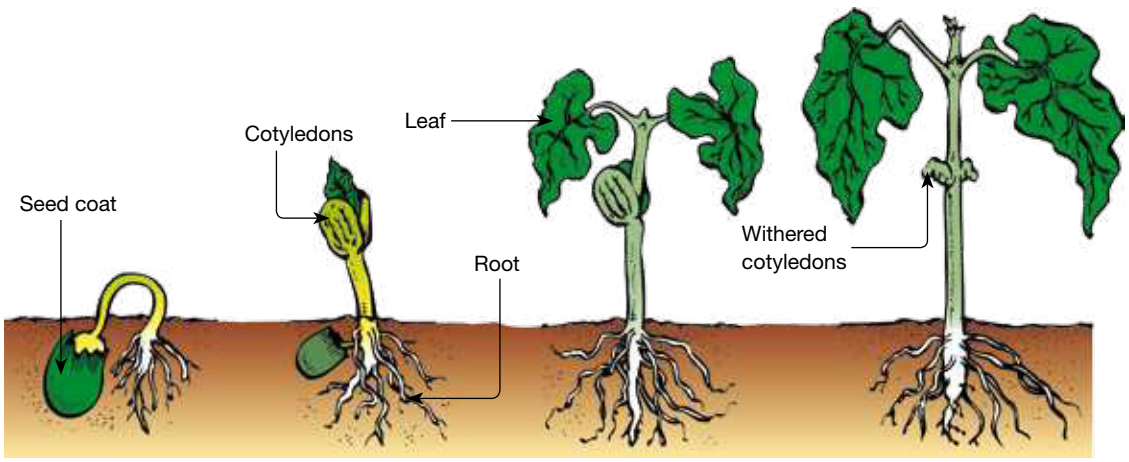
There are three environmental conditions that are needed by all seeds before they can germinate: water, oxygen and a certain temperature, usually warm. **Water** is necessary for the seed to swell and burst open and then to transport food to the growing embryo. Oxygen is required to help provide the energy needed for growth and development. The required temperature depends on the particular type of plant.

Some Australian plants, such as *Banksia* and mountain ash (*Eucalyptus regnans*), require high temperatures to burst the fruit so that the seeds may be released. This adaptation gives these plants an excellent chance of survival in regions prone to bushfires.

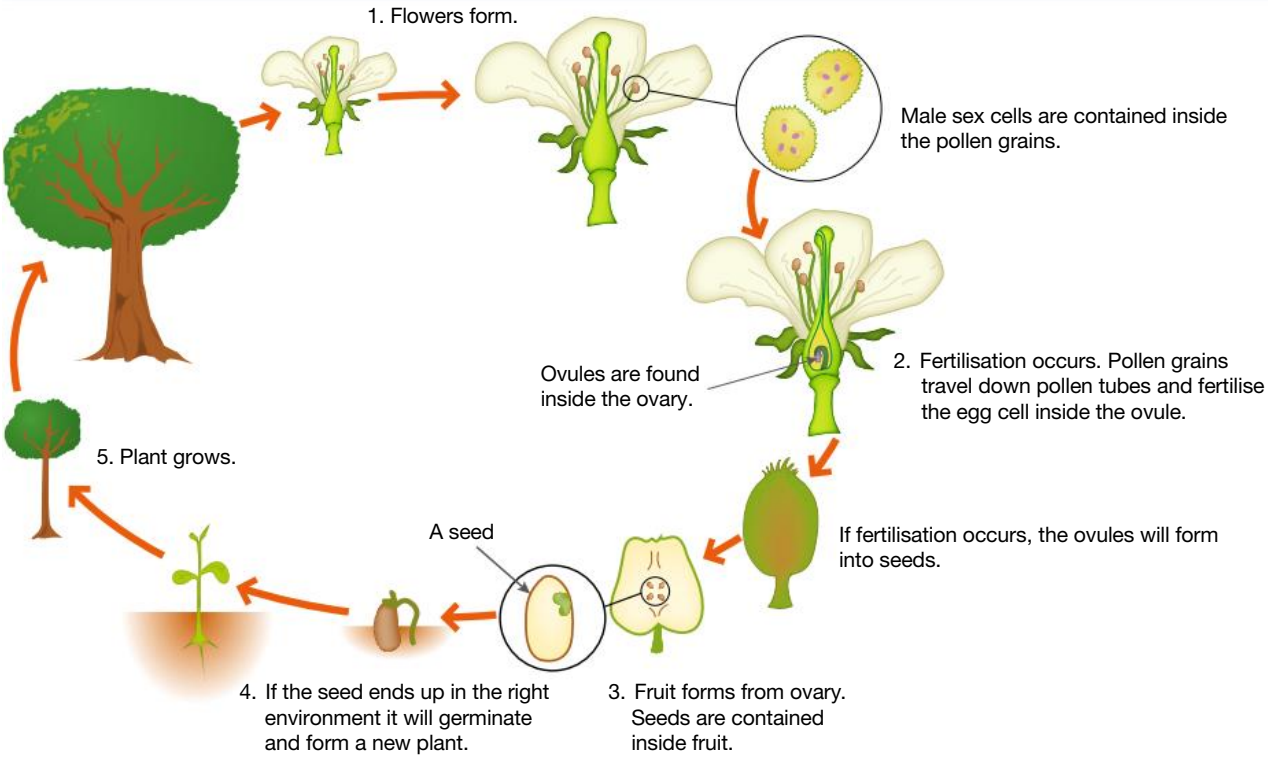
Although **light** is not necessary for the germination of most seeds, it is needed once the young shoot breaks through so that the plant can make its own food.

The diagram below summarises the life cycle of flowering plants.

Germination of a broad bean



The life cycle of a flowering plant



INVESTIGATION 13.6

Seeds — watch them grow

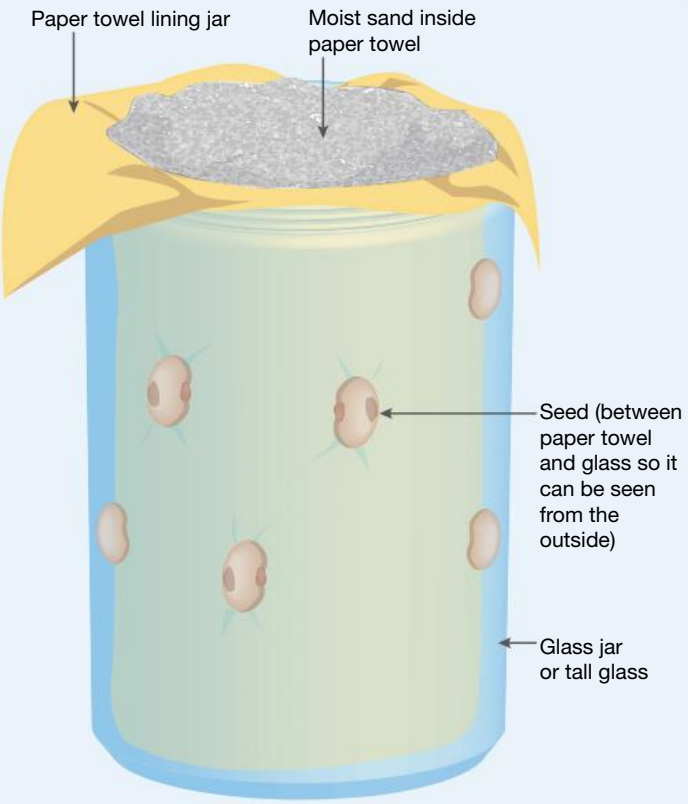
AIM: To compare the germination of different types of seeds

You will need:

2 maize seeds, 2 sunflower seeds and 2 beans soaked for at least 24 hours
gas jar or tall glass
paper towel
sand

- Line the inside wall of the gas jar with a double layer of paper towel.
- Pour some sand inside the jar until it is about one-third full.
- Place the seeds between the paper towel and the glass (so that you can see them from the outside of the jar). Ensure that they are spread around the jar so that each seed will have plenty of room.
- Add more sand to the jar. This will keep the paper towel pressed against the sides of the jar.
- Pour water over the sand until all the sand in the jar is moist.
- Observe each seed daily for three weeks.

How to set up this experiment



Discussion

1. Record how many days it takes for each seed to germinate. Once the seeds have germinated, use a table to record the lengths of any observable shoots and roots each day.
2. After three weeks, draw a diagram of one of the plants. Label the shoot, roots and leaves.
3. Draw a graph showing how the length of the shoot of each plant changed over time.
4. Did the three different types of seed grow the same way? Describe the similarities and differences.
5. Did you obtain the results that you expected? Explain.
6. Write a conclusion on the basis of your findings.

13.7 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** which part of a flower develops into a fruit after fertilisation.
2. **Describe** the conditions needed for germination.
3. **Explain** why light is usually necessary only after the plant has germinated.
4. If birds eat the seeds of fruit, **explain** how the seeds can be dispersed.

Think

5. **Construct** a mind map showing some foods that are seeds or that are the products of seeds.

Investigate and design

6. Design an experiment to **investigate** whether water affects the germination of a variety of different types of seeds.
7. **Investigate** where the germinating seed gets its food from and report back in a diagram.
8. Find seeds or pictures of seeds and **classify** them according to how they are dispersed. Try an internet search using the key words 'seed dispersal'.

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Complete this digital doc: Worksheet 13.9: Seeds (doc-12464)

13.8 Plant research project

Science as a human endeavour

13.8.1 Choosing a problem

It's your turn to be a scientist! In the following investigation, you will design and carry out an experiment involving plants. You will also prepare a scientific report about your experiment.

Deciding on a problem to solve is often the hardest part of a research project. The following pointers may help you:

- In your experiment, you will need to deliberately change one of the **variables**. This could be:
  - the amount of water
  - additives to water (such as sugar, salt, caffeine or vitamin C)
  - type of growth medium (such as sand, garden soil or gravel)
  - amount of light (You could use different types of shadecloth.)
  - colour of light. (You could use coloured cellophane over the pots.)

The variable you change deliberately is the **independent variable**.

- You will need to decide what to measure. The thing you measure is called the **dependent variable**. Examples of things you could measure include:
  - time taken for seeds to germinate
  - height of the shoots each day
  - number of leaves on each plant
  - mass of seeds produced by each plant.
- You will need to make sure that the experiment is fair. That means that all variables except the independent variable should be kept the same (**controlled**).
- You must also include **controls**. For example, if you wanted to find out how plants were affected by salty water (independent variable), you might give three plants salty water. You would also need to give a second group of plants normal tap water (the control). The only difference between the two groups of plants should be that one group gets salty water while the other gets normal tap water.

If you were testing several groups of plants with different amounts of salt, you would still need to give one group of plants normal tap water. The plants with tap water are the control in the experiment. It shows whether the salt (independent variable) has an effect on plant growth (dependent variable). The control is used for comparison to see if the independent variable has an effect. If you were testing different types of soil, you would need to ensure that all other variables (controlled variables) are the same for each group of plants.

You need at least two groups of plants.



1. If you were testing the effect of different types of shadecloth on the growth of plants, describe the conditions under which the control group should be grown.
2. Write a brief plan for your investigation. Read the next section, 'Conducting the investigation' before you start. Include in your plan:
   (a) what you want to find out (the **aim** of your investigation)
   (b) a list of materials that you will use
   (c) an outline explaining how you will make sure that your tests are fair.

13.8.2 Conducting the investigation

1. Make sure you use at least 10 seeds or seedlings for your experiment.
2. If you are using seeds, you will need to soak them in water overnight before starting the experiment.
3. There are a few ways to set up the experiment. To investigate germination, you could use the same apparatus as in *Investigation 13.6*, or you could put the seeds on moist cotton wool in a dish. To investigate the growth of plants, you could plant the seedlings in soil or potting mix and wait for them to poke through the soil. If you are short of time, you may want to use seedlings rather than seeds for your experiment. The pictures at the top of the next page show some ways to set up plant experiments.
4. Prepare a table in which you can record the progress of your plants for three to four weeks. Use the sample table at the bottom of the next page as a guide. It can be used like a diary to keep all your observations and measurements together.
5. Predict what you expect to find out. This is your **hypothesis**.

Planting your seeds

Step 1
Press a hole about 2 cm deep into the potting mixture with a pencil.

Step 2
If you are planting more than one plant in each container, mark the position of each seed by sticking a toothpick beside it.

Step 3
Label your container with your name and the date and any other vital information, e.g. 'salty water', 'red light'.

Step 4
Water your seeds, but take care not to overwater! Leave your seeds in a warm and sunny position.

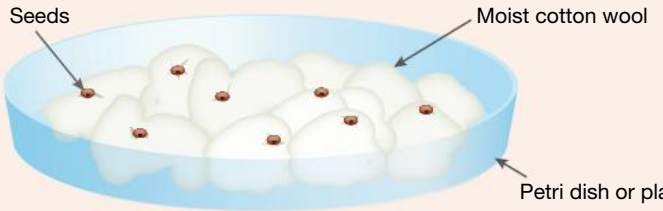


Step 1
Put some cotton wool in a Petri dish or plate. Add enough water to moisten the cotton wool. Place the pre-soaked seeds on top of the cotton wool.

Step 2
Water the seeds as required to keep the cotton wool moist, but do not overwater as mould will grow on the seeds.

Another way to set up your experiment

Step 1



Step 2



Sample table. This table could be used to record the results for an experiment to find out if watering plants with salt water affects their growth.

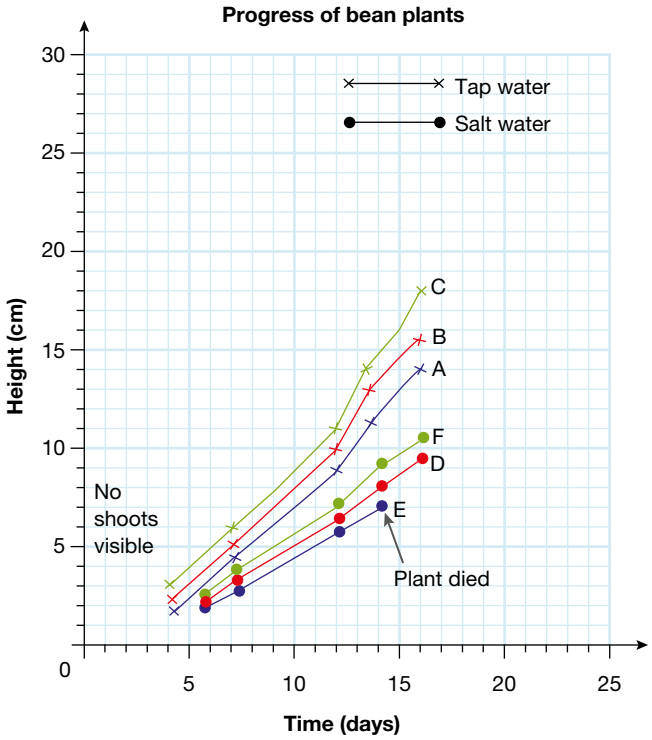
			Height of seedling (mm)												
			Tap water						Salt water						
Date	Day	What I did	A	B	C	D	E	Ave.	A	B	C	D	E	Ave.	Observations and diagrams
5/3	10	Watered all plants a 3 pm; gave each plant 50 mL water	7.1	8.0	8.9	7.5	8.2		5.0	4.4	5.8	4.8	5.2		

13.8.3 Using your data

While your plants are growing, you can record the progress of the plants on a line graph like the one at right. This graph shows how the height of two groups of six plants changes. You could use graphs in a similar way to show how the number of leaves changes or how many seeds germinate each day.

If any of your plants die, your investigation is not a failure. You must, however, make a reasonable attempt to explain why they died.

Use a graph to record the progress of your plants. The independent variable is on the *x*-axis; the dependent variable is on the *y*-axis.



13.8.4 Writing your report

In reporting your investigation to others, you should use the headings listed below. You will find a description of what should be included under each heading in Section 17.10 of this book.

- Aim (purpose)
- Procedure (materials and method)
- Results (your observations and measurements, including tables, graphs or photos, if appropriate)
- Discussion (including evaluation of method and results)
- Conclusion (a statement about the key findings in your experiment, which must be related to the aim)

Also, make sure that you give your report an appropriate title. Possible titles for this investigation are:

- 'The effect of _____ on the growth of bean plants'
- 'The effect of _____ on seed germination'.

13.8 Exercise: Remember and think

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Think

1. In the table opposite, five bean plants are watered with each type of water. **Explain** why this is better than testing just one plant with each type of water.
2. Genevieve is investigating the effect of shadecloth on the growth of bean plants at home. She places three plants under the pergola at the back of her house, which is covered with shadecloth. She places the other three against the wall at the front of the house. All plants are in the same size pots and are given the same amount of water. **Describe** how Genevieve could improve her experimental design.
3. Cameron is trying to find out whether sand or garden soil is better for growing radishes. He also wants to find out if sugar added to the water that is given to plants makes a difference. Cameron plants three seeds in sand and three seeds in garden soil. The plants growing in sand are watered with tap water. The plants growing in garden soil are given the same amount of a mixture of sugar and water.
   (a) What two questions is Cameron trying to answer with his experiment?
   (b) **Identify** the major problem with Cameron's experimental design.
   (c) Is it possible for Cameron to design a better experiment to answer both of his questions with only six seeds? **Explain** how.
4. **Summarise** what you know about scientific method and reports into a mind map or another visual map.

Investigate

5. **Propose** how a plant would grow in a container that is upside down. Design and perform an experiment to find out.
6. **Propose** how a plant would grow in a fully enclosed container with a hole in one side. Design and perform an experiment to find out.
7. Can a plant grow without soil? Design and perform an experiment to find out.

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Watch this eLesson: Growing plants in Australia (eles-0055)

13.9 All about the birds and bees

13.9.1 Fertilisation

It's time to look at how animals reproduce. In most instances animals have two parents, they reproduce sexually and inherit features from both parents.

In sexual reproduction a female sex cell and a male sex cell must combine to form a zygote — the first cell of the offspring. This process is called fertilisation. Fertilisation can occur inside or outside the body of animals. After fertilisation has occurred, the zygote must grow and develop. This can also happen both inside and outside the body.

Fertilisation involves the fusion of gametes or sex cells. When a male gamete combines with a female gamete, a zygote is formed. External fertilisation, as the name suggests, occurs outside the body, while internal fertilisation occurs inside the body.

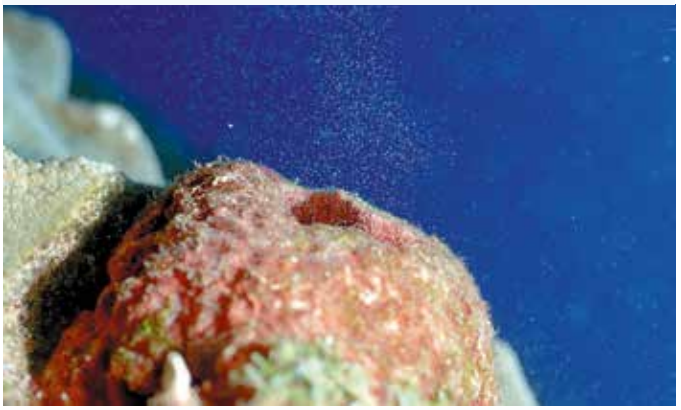
External fertilisation

In aquatic organisms that reproduce sexually, fertilisation usually occurs externally. Eggs and **sperm** are released into the water and fertilised outside the body. This poses many risks for 'would-be' zygotes! For a start, the gametes need certain conditions to survive — these are not always met in the environments into which they are released. Many gametes don't connect, so fertilisation never occurs. Those zygotes that do form may get eaten, battered by strong tides or killed by pollutants in the water.

It is no wonder that so many eggs and sperm cells are so often needed with external fertilisation!



During a few nights each year, coral colonies release clouds of male and female sex cells into the water. (Most corals are hermaphrodites, which means they produce both eggs and sperm. Amazingly, the eggs have chemicals to attract sperm from different colonies of the same species.) The animal embryos that form after the eggs are fertilised float to and fro. If they do not die, or get eaten, they settle down after a few days. These tiny coral polyps (small animals) continue to develop into new colonies of coral. (A coral reef is made of up these animals' skeletons.)



13.9.2 Internal fertilisation

With internal fertilisation, a **sperm cell** fuses with an **ovum** inside the body (almost always the female body). In many species, this is the result of sexual intercourse, during which a male inserts his erect **penis** into a female's **vagina**. Here sperm (male gametes) are deposited when **semen** is **ejaculated** (that is, released from the penis). Survival prospects for internal fertilisation are better than for external fertilisation. For a start, the environment inside the body is not subject to unpredictable events, such as a tidal surge or the sudden arrival of predators! Also, the temperature is just right.

Kangaroo joey attached to a teat inside the mother's pouch



After internal fertilisation, the zygote can be expelled out of the body as an egg or it can remain inside the body of the female to grow and develop. Fish, reptiles, amphibians, birds and monotreme mammals all lay eggs. The offspring then develops inside the egg over time. Since the eggs of fish and amphibians are laid in water and are not at risk of dehydration, they do not have a shell and appear jelly-like, whereas eggs that are laid on land need a shell to keep moisture inside the egg. The eggs contain a supply of nutrients for the growing embryo, while oxygen can pass through the shell. When the animal outgrows its egg or runs out of nutrients, it emerges from the shell. Some animals such as turtles lay their eggs and leave them unsupervised until they are ready to hatch. However, other animals such as birds sit on their eggs to keep them warm and protect them from predators.

A kangaroo's pouch is a safe place for a joey to develop.



To keep their offspring safe while they are developing, mammals have evolved some interesting strategies. Marsupial mammals are about the size of a jelly bean when they are born. They are not fully developed but manage to crawl into a pouch on their mother's stomach and attach themselves to a teat so they can receive milk. There they continue to grow and develop until they are ready to start eating foods other than milk. The joey then ventures out of the pouch for increasingly long periods of time until it becomes too large for the pouch and its mother makes it clear that it is no longer welcome.

Placental mammals such as humans keep their babies in the uterus inside their bodies. A structure called the placenta provides nutrients and oxygen to the developing baby and removes the baby's waste. All mammals produce milk to nourish their babies after birth.

13.9.3 Different ways of having babies

Is it a boy? A girl?

Earthworms — like many flowering plants, snails and coral — are hermaphrodites. This means they have both male and female reproductive organs and so can produce both eggs and sperm. But earthworms still need mates to reproduce.

Two earthworms in the process of reproduction



First, the earthworms swap each other's sperm, depositing it in special openings in the body. Then a swollen area near each worm's head, called a clitellum, produces mucus that slides down over the head of the worm like a tiny tube. The worm lays a few eggs in it and adds a few of the sperm cells deposited by the other earthworm. Then the tube is tied off to form a little cocoon. If soil conditions and temperature are right, the **embryos** hatch in about three weeks.

Swallowing babies

The recently extinct gastric brooding frog had an unusual way of keeping its young safe. The female would swallow the eggs after fertilisation. The eggs then developed into tadpoles and eventually into small frogs inside her stomach. When the froglets were sufficiently developed, they were regurgitated by their mother.

Dad's having babies

In placental mammals, babies develop inside the mother's body. Seahorses do things differently. It is the female that inserts part of her body (an ovipositor) into the male. She pumps eggs into a pouch at the front of his body and he then fertilises them with his sperm. Labour can sometimes take two days. Poor dad gives birth to 50–100 little seahorses, squeezing them out, one at a time. No wonder he's called a big-bellied seahorse.

Male *Hippocampus abdominalis* seahorses try to get females to select them to carry eggs by inflating their pouches into a white balloon.



There are some amazing stories to tell about other types of seahorses. The male *Photocorynus* seahorse never grows larger than 10 cm and leads a parasitic life in which he is permanently attached to the female, hanging on by his mouth! This is useful to the female because it means that she doesn't have to search dark ocean depths to find a mate when her eggs are ready for fertilisation.

13.9 Exercise: Remember and think

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Remember

1. **Define** the term 'fertilisation'.
2. **Classify** the following animals into groups using a table similar to the one shown below.
   cat, cane toad, bird, human, coral, snail, brown snake, gold fish, funnel web spider, fly, gastric brooding frog, seahorse

		Fertilisation	
		External	Internal
Embryo development	External		
	Internal		

3. **Describe** why male seahorses are unusual fish.
4. **Contrast** the following pairs.
   (a) A bird's egg and a frog's egg
   (b) Placental mammals and marsupial mammals
5. **Explain** what a hermaphrodite is. Give three examples.
6. (a) **Explain** the difference between internal and external fertilisation, giving examples.
   (b) Which method of sexual reproduction provides the best chances of survival? Why?

Think

7. Many fish carry out courtship displays before releasing their egg and sperm in the water. **Propose** why.
8. **Propose** a reason why coral spawn simultaneously (all corals release their gametes simultaneously).
9. **Explain** why internal fertilisation is generally more efficient than external fertilisation.

Investigate

10. Find out more about the reproductive systems and mating behaviours of two different animals. Draw up a summary table to **describe** how are they similar and how are they different.
11. Use the **Animal video** weblink in the Resources tab to access the National Geographic video site. Type the word 'courtship' in the search bar to view examples of courtship displays. List some animals that carry out courtship displays.
12. Test your understanding of plant reproduction by using the **Plant life cycle** weblink in the Resources tab and complete the drag-and-drop activity.

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Complete this digital doc: Worksheet 13.10: Sexual reproduction (doc-12465)

Explore more with this weblink: Animal video

Explore more with this weblink: Plant life cycle

13.10 Where do babies come from?

13.10.1 The male repoduction system

It's difficult to believe that you started out as just one cell in your mother's reproductive tract. Let's find out how it all began, starting with your private parts.

Although testes and ovaries may look different, these two organs have the same job. They both make gametes.

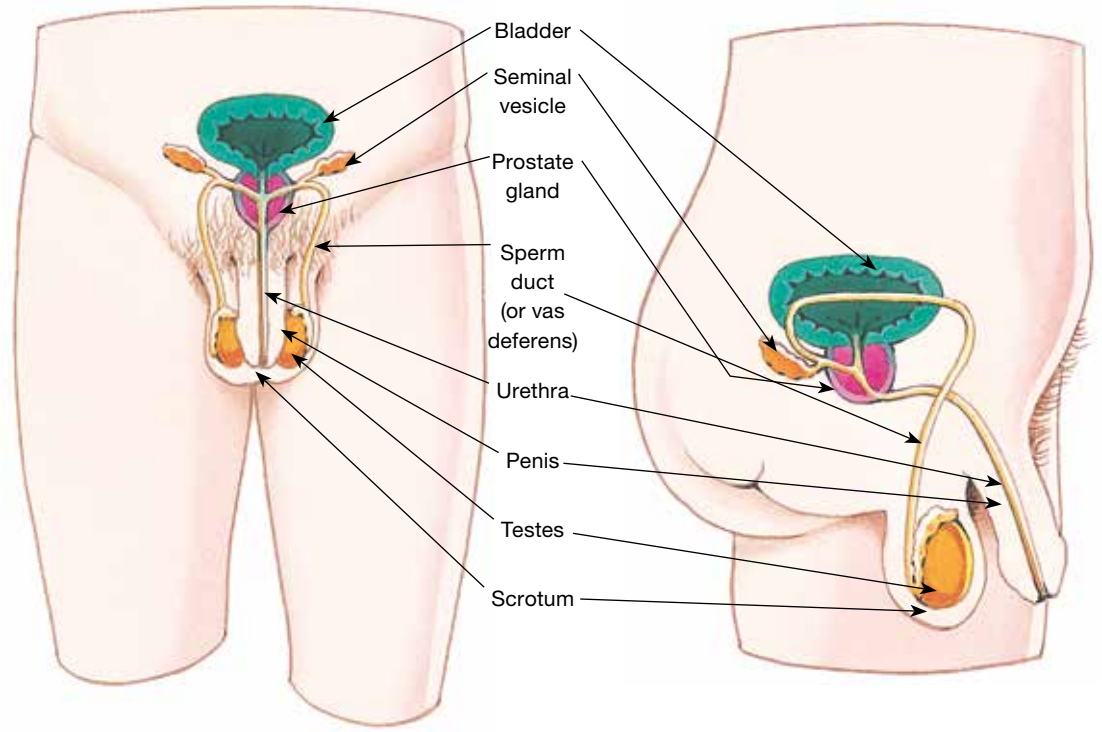
Sperm are made in the **testes** of a male when he is sexually mature. Testes hang from the body within the **scrotum** to maintain sperm at a temperature of about 3°C below that of the rest of the body. This temperature difference is essential for successful sperm production. Tight underwear or jeans can increase the temperature of the testes and so increase the number of damaged sperm produced.

HOW ABOUT THAT!

Sperm by the millions

The average amount of semen produced during an **ejaculation** (about a teaspoonful) contains about 200–500 million sperm cells! You might think it would take a long time for the testes to make 400 million sperm. Not so. Some 200 million sperm cells are manufactured each day by a fertile adult male. That's around 73 billion sperm cells in a year!

The male reproductive system



Parts of the male reproductive system

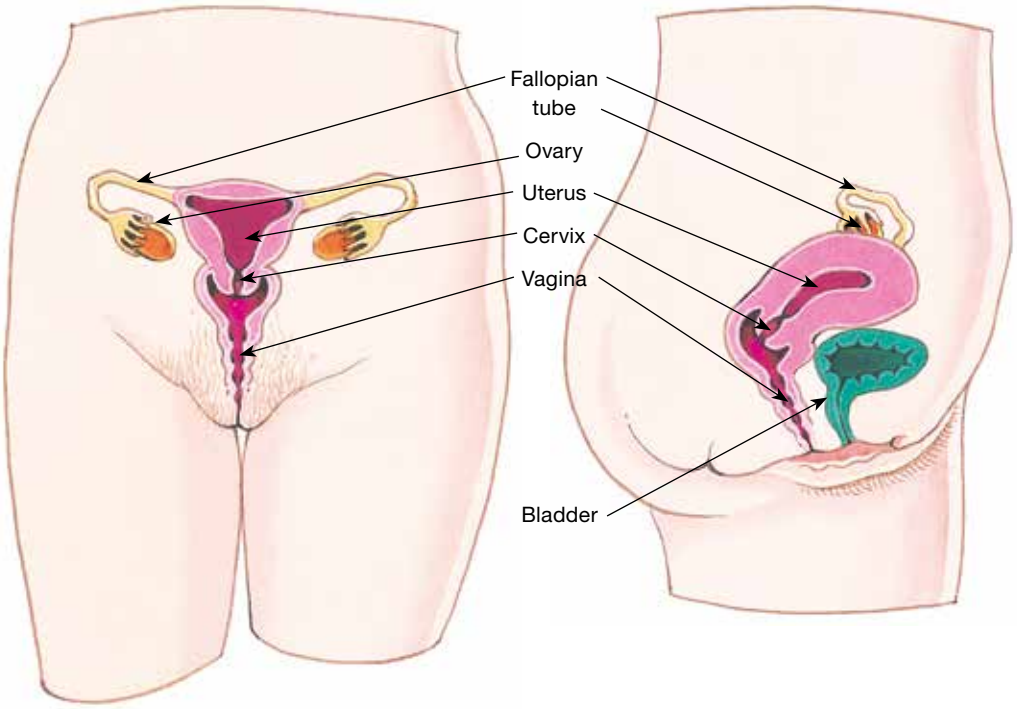
Part	Function
Testes	Produce sperm cells
Scrotum	Where the testes are located. Keeps the testes at a slightly lower temperature than body temperature.
Vas deferens	The tube through which sperm cells travel from the testes to the penis
Prostate gland	Secretes some of the liquid that is added to sperm 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.

13.10.2 The female reproductive system

Ova (the female's sex cells) are made in the ovaries. Females are born with about 1 million immature eggs, or ova, in their ovaries. These eggs are in sacs called **follicles**. Usually only one ovum (plural = ova) is ripened and released into the **fallopian tube** (or oviduct) each month.

Fallopian tubes are thin tubes that form a tunnel in which the sperm and ovum meet, and are hence the site of **fertilisation**. Damage to these tubes can prevent the sperm and egg from meeting.

The female reproductive system



Parts of the female reproductive system

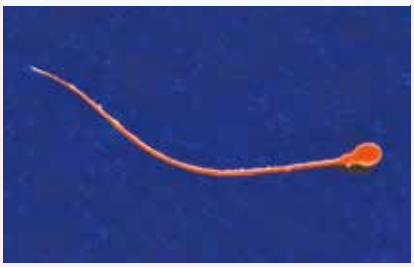
Part	Function
Ovaries	Produce ova. One egg is produced about once a month from one of the ovaries.
Fallopian tubes/ oviducts	Tubes through which ova must travel to reach the uterus. Fertilisation occurs in the fallopian tubes.
Uterus	Where the baby grows and develops
Cervix	The passageway between the vagina and the uterus. 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.

HOW ABOUT THAT!

Amazing sperm

Sperm cells are less than half a millimetre long. Viewed through a microscope lens, spermatozoa (sperm, for short) remind you of tadpoles — a big head and a thin, whippy tail. They form in the testes, but only when the temperature is just right — a few degrees lower than body temperature. This is where the scrotum — a natural thermostat — does its job. It shrivels and scrunches up closer to the body when you are cold (keeping sperm warmer) and hangs away from your body when you are hot (cooling them down).

A sperm cell under a microscope

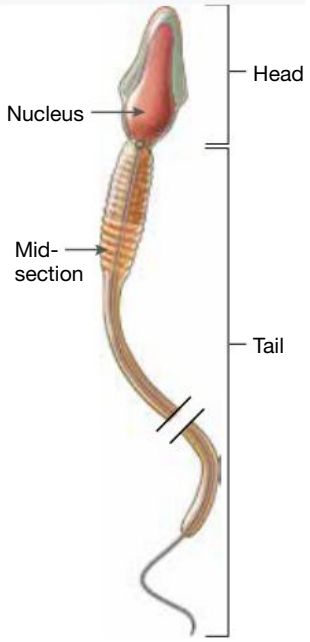


13.10.3 Sperm meets egg

Healthy adult males produce sperm cells continuously. Females on the other hand produce only one egg about every 28 days. If sexual intercourse occurs around the time that this egg is released, a new life may begin. During sexual intercourse, semen containing sperm cells is ejaculated into the vagina. The sperm cells

swim through the **cervix**, into the uterus and up into the fallopian tube. If one of the sperm cells meets up with the egg cell and fertilises it, a zygote is formed. The semen of a fertile man typically contains more than 20 million sperm cells per millilitre. While only one sperm cell can fertilise the egg, it is thought that the other sperm cells play an important role in assisting the process of fertilisation. The sperm cells may in fact cooperate and help each other out on their perilous journey through the female reproductive tract.

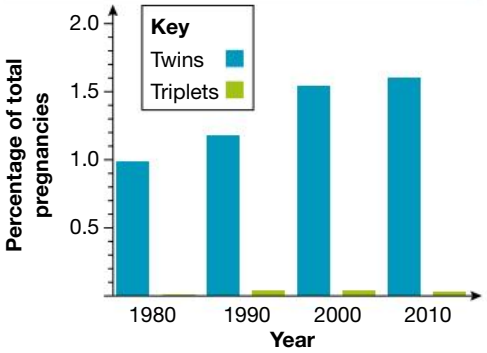
Sperm cell



13.10.4 Twins and more

Human beings usually produce only one baby at a time when they reproduce naturally. On average, twins are born every 80 or so human births; more rarely, triplets are born (one set about every 6000 births).

Incidence of multiple births in Australia since 1980 (as a percentage of total number of pregnancies)



Source: Based on ABS data

13.10.5 Not all twins are identical

Some twins look very similar but others look no more like each other than any set of siblings. It depends whether they are identical or fraternal twins.

Identical twins occur when the zygote divides into two identical cells. Instead of those two cells 'sticking together' and continuing to redivide, they separate and develop into two separate embryos. Because they have exactly the same mix of genes (i.e. the same DNA), the twins are the same gender and have the same physical appearance.

Fraternal twins occur when two separate sperm cells fertilise two separate ova, which are released at around the same time (an unusual occurrence). The genetic mix of fraternal twins is different. They are no more alike than siblings.

Identical twins



Fraternal twins



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. Draw a table as shown below. **Classify** the following organs and list them in the correct column of your table.
   fallopian tube, penis, urethra, testes, prostate gland, bladder, uterus, seminal vesicle, ovary, vas deferens, scrotum, cervix, vagina

Found in males only	Found in females only	Found in both males and females

2. Match each organ with its function. There may be more than one organ with the same function.

Organ	Function
(a) Seminal vesicle	A Produces gametes
(b) Ovary	B Where the baby grows and develops
(c) Scrotum	C Where fertilisation occurs
(d) Testes	D Keeps the testes slightly cooler than the rest of the body
(e) Prostate gland	E The passageway between the vagina and the uterus
(f) Uterus	F Produces some of the liquid found in semen
(g) Cervix	
(h) Fallopian tubes	

3. Put the following words into a sentence.
   gametes, sperm, ovum, zygote, fertilisation

Think

4. **Explain** why tight underwear is not recommended for males.
5. **Account** for the fact that women who have blocked fallopian tubes are not able to have babies.
6. **Distinguish** between fraternal and identical twins.

Investigate

7. A low sperm count is one possible cause of infertility in males. What else can go wrong with sperm cells? **Investigate** and **outline** some of the reasons why sperm cells may not be able to fertilise egg cells.

Create

8. Imagine that you are a sperm cell that is released into the vagina and successfully fertilises an egg. **Recount** your trip from the time of ejaculation to fertilisation.

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Complete this digital doc: Worksheet 13.11: Human reproduction (doc-12466)

13.11 Womb with a view

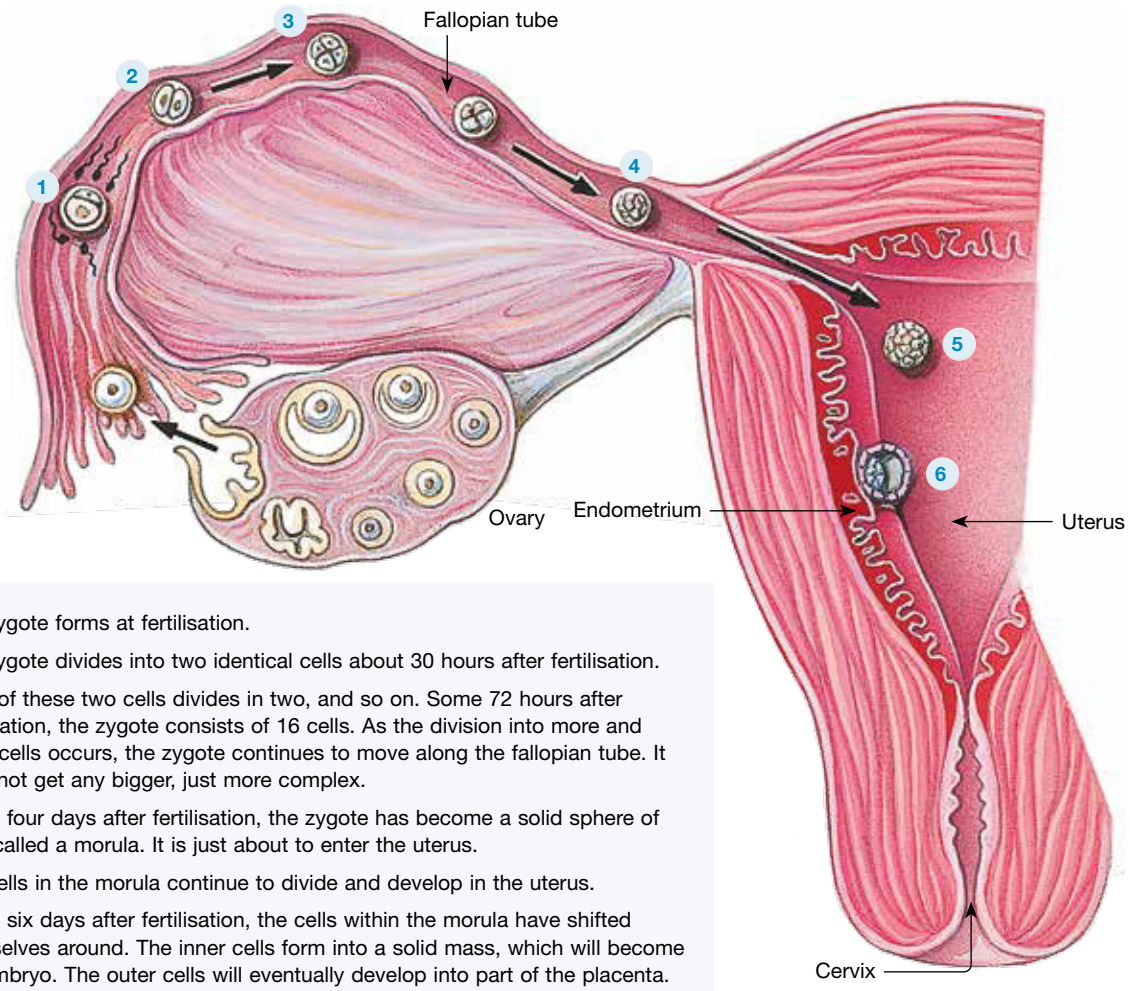
13.11.1 What happens to a fertilised egg?

Babies grow and develop inside the womb for 9 long months. Over that time they change from a bunch of cells into a functioning human being equipped with all the organs needed for life outside the uterus. Let's take a look at how it all happens.

A short while after the egg is fertilised, the zygote starts dividing. It also continues to travel towards the uterus. About 6 days after fertilisation, the zygote may implant itself into the wall of the uterus.

HOW ABOUT THAT!

Fertilisation does not always happen inside the body. Some couples find it difficult to conceive a child naturally. There are many factors that can reduce a couple's fertility. The woman's fallopian tubes might be blocked, or there might be a problem with the man's sperm. A technique called in-vitro fertilisation, or IVF, can often increase the couple's chance of having a baby. In this procedure, one or more eggs are extracted from the woman's ovary and placed in a dish. Sperm, from either the woman's partner or a donor, is then added. If fertilisation is successful, the egg begins to divide in the dish. After a few cell divisions, the embryo can then be placed in the woman's uterus. If it implants, it can then continue to develop normally in the mother's womb.

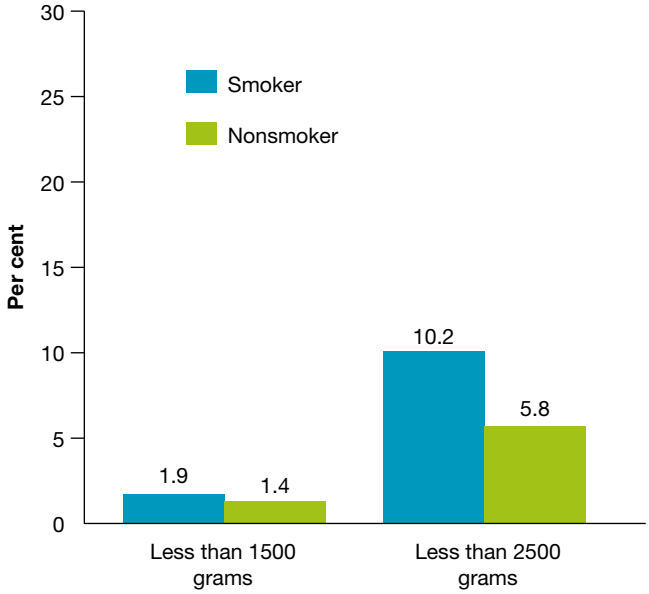


1. The zygote forms at fertilisation.
2. The zygote divides into two identical cells about 30 hours after fertilisation.
3. Each of these two cells divides in two, and so on. Some 72 hours after fertilisation, the zygote consists of 16 cells. As the division into more and more cells occurs, the zygote continues to move along the fallopian tube. It does not get any bigger, just more complex.
4. About four days after fertilisation, the zygote has become a solid sphere of cells called a morula. It is just about to enter the uterus.
5. The cells in the morula continue to divide and develop in the uterus.
6. About six days after fertilisation, the cells within the morula have shifted themselves around. The inner cells form into a solid mass, which will become the embryo. The outer cells will eventually develop into part of the placenta. At this point, the former zygote implants itself in the lining of the uterus, called the endometrium. (It is this lining, along with blood and mucus, that is shed each month during menstruation.)

13.11.2 The placenta

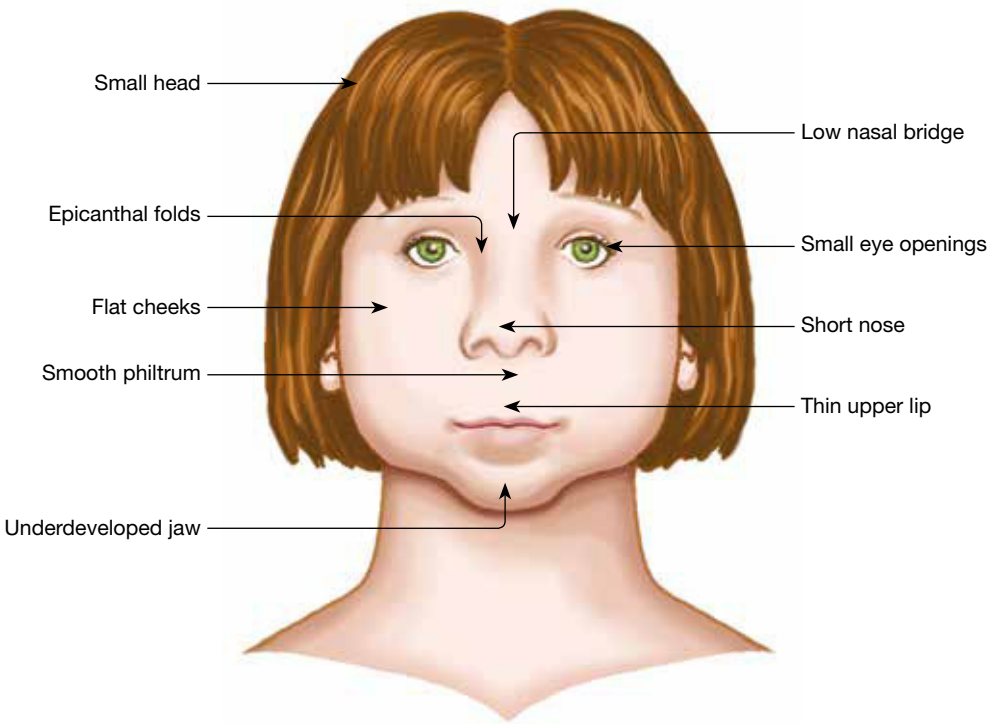
After implantation the placenta begins to form. This is a structure that is embedded into the wall of the uterus and is connected to the baby by the umbilical cord. The baby and the mother do not share the same blood supply. In fact it is common for a mother and baby to have different blood types. The role of the placenta is to allow useful substances such as oxygen and nutrients to pass from the mother's blood into the baby's blood. Carbon dioxide and other waste must also pass from the baby's blood into its mother's so that she can excrete these. If the placenta does not function properly, the baby may die as it will not receive sufficient oxygen and nutrients, and waste will accumulate in the amniotic fluid (the liquid around the baby).

The average weight of a newborn baby is 3500 g. Women who smoke during pregnancy are at greater risk of giving birth to an underweight baby.



Unfortunately, harmful substances including medication, drugs, alcohol, caffeine and substances in tobacco smoke can pass through the placenta. When a pregnant woman smokes or drinks alcohol, her baby does too. Drinking large quantities of alcohol during pregnancy can result in the baby having a condition known as fetal alcohol syndrome. The symptoms vary according to the stage of pregnancy during which the alcohol was consumed but may include mental retardation, slow growth, heart problems and a particular set of facial characteristics. The exact amount of alcohol needed to cause damage is difficult to determine. Alcohol can cause serious health effects even in the early weeks of pregnancy when a woman may not yet know that she is pregnant. For this reason doctors advise that women do not

Some of the facial characteristics that may occur in children with fetal alcohol syndrome



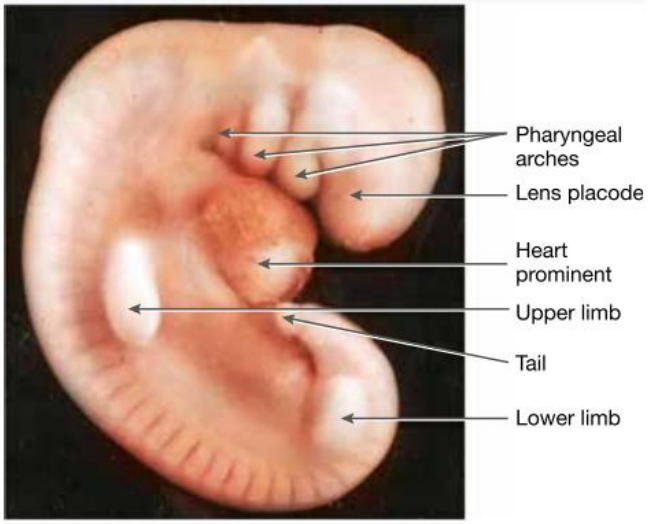
drink if they are or think they might be pregnant. Similarly, smoking and drinking large amounts of coffee, tea or other caffeinated drinks during pregnancy is not recommended. The babies of women who smoke during pregnancy are more likely to be born underweight and to develop asthma and other respiratory problems. They are also at greater risk of cot death.

13.11.3 Getting bigger

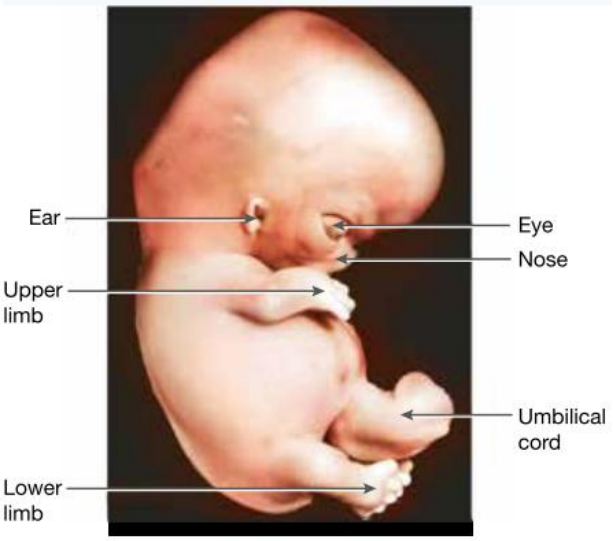
The developing baby spends the entire gestation period in a sac within the uterus filled with **amniotic fluid**. In fact, it does not take its first breath of air until it is born.

Eight weeks into the gestation period, the embryo is called a **fetus**. It weighs about two grams and is about three centimetres long. It can move, and has tiny developing limbs and a distinct head. Its developing heart started beating four weeks earlier, when it was about six millimetres long.

A human embryo at 32 days



A human embryo at 52 days



13.11.4 Entering the world

Sometimes babies are born by **caesarean section**. This may occur if the mother is at risk in giving birth naturally, or if the baby is in distress and has to be removed quickly. Most mothers, though, expel babies from their uterus through the vagina naturally through a process called labour, described on the next page. A healthy full-term (40 weeks) baby is, on average, about 53 cm long and weighs about 3.5 kg.

The developing baby

12 weeks About 8 cm long and 18 g in weight. Can swallow and move head. Eyes are closed, but formed. Gender is evident.

16 weeks About 18 cm long and weighs about 120 g. Has a unique fingerprint and the ability to cry (if not immersed in fluid!).

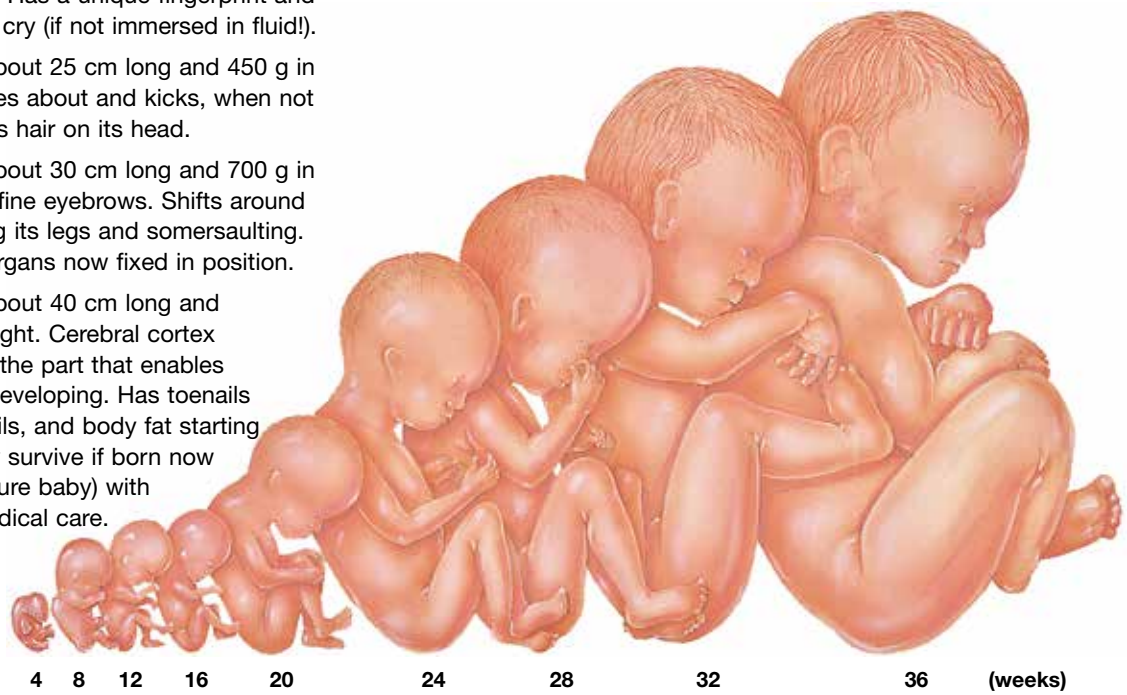
20 weeks About 25 cm long and 450 g in weight. Moves about and kicks, when not sleeping. Has hair on its head.

24 weeks About 30 cm long and 700 g in weight. Has fine eyebrows. Shifts around often, kicking its legs and somersaulting. All internal organs now fixed in position.

28 weeks About 40 cm long and 1.2 kg in weight. Cerebral cortex of the brain (the part that enables thinking) is developing. Has toenails and fingernails, and body fat starting to form. May survive if born now (as a premature baby) with intensive medical care.

32 weeks About 45 cm long and 2 kg in weight. Most are head down now. Can hear sounds, including the mother's heartbeat.

36 weeks About 50 cm long and 3.3 kg in weight. Body fat increases. Heart rate almost twice that of an adult human. May suck its thumb.



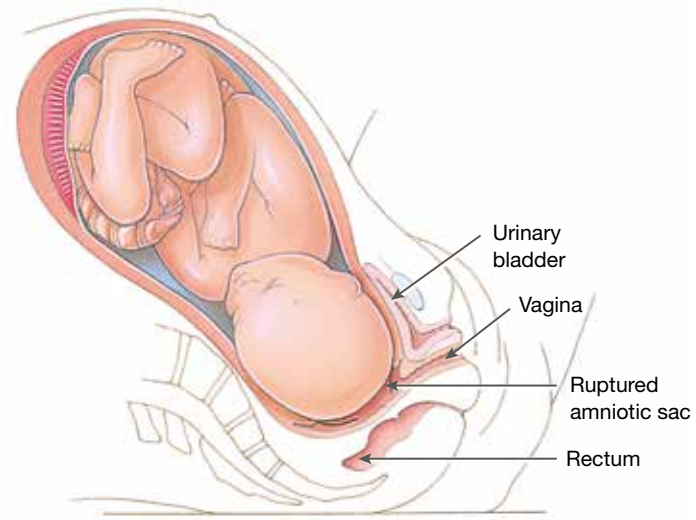
First stage

Uterus begins to contract at regular intervals, which get closer and closer together. These contractions begin pushing down on the baby.

At some point, the sac holding the amniotic fluid breaks; the fluid leaks out of the mother's vagina.

As contractions continue, the **cervix** stretches open more and more, until it is about 10 cm wide.

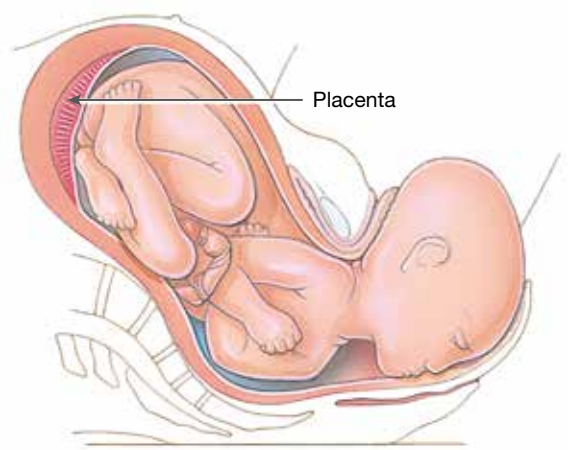
This stage can last for many hours, especially for first-time mothers.



Second stage

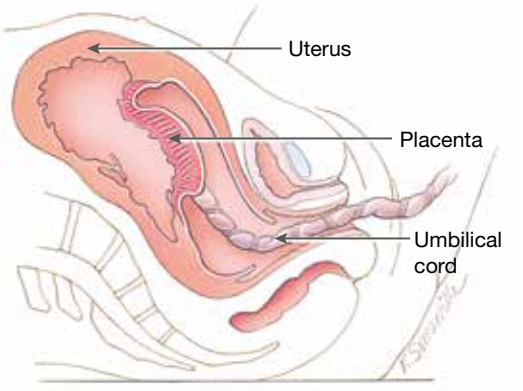
The mother gets a fierce urge to push (a bit like with a bowel motion) every time the uterus contracts. Bit by bit, this pushes the baby further down the vagina (birth canal).

Most babies appear head first; those that come out feet first (or bottom first) — called breech babies — are more difficult and risky to deliver.



Third stage

The placenta is delivered after the baby is born. By this stage of the pregnancy it is a flattish, dinner-plate-shaped organ that looks a bit like a large piece of liver.



13.11 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. **Construct** a timeline, drawn to scale, that shows the events listed below. Some of the events may be shown as a time range (for example ovulation could occur before or after sexual intercourse).
   fertilisation, zygote consists of 16 cells, birth, sexual intercourse, ovulation, zygote implants in uterus, zygote divides into two cells, zygote has become a morula and enters the uterus
2. **Describe** the role of the placenta in the baby's development.
3. **Outline** what a caesarean section is and why it may be necessary.
4. Unscramble the order of words in the following sentence so it reads correctly:
   with The sac gestation spends the period entire a in developing the filled uterus amniotic within fluid baby.

Think

5. Look very carefully at the two photographs of human embryos. Use these to help you **describe** what obvious physical changes occur in a human embryo between days 32 to 52 of its development.

6. You might have heard women describing their labour use the expression ‘my water broke’. **Describe** what this actually involves.
7. Study the graph. Knowing that an average baby weighs 3500 g at birth, **interpret** the data shown in the graph. Write at least two sentences that **explain** what the graph shows.

Discuss

8. **Propose** some strategies that the NSW Department of Health could put into place to try to reduce the number of babies born with fetal alcohol syndrome and conditions caused by smoking during pregnancy.
9. The percentage of babies delivered by caesarean section has increased over the last 10 years in Australia. Suggest why this might be the case.

Investigate

10. Find out which substances apart from alcohol and cigarette smoke are considered teratogenic (teratogenic substances can cause harm to unborn babies). **Summarise** the information you gather.
11. Find out how an ultrasound machine works. **Evaluate** the benefits of carrying out ultrasound scans during pregnancy.

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Complete this digital doc: Worksheet 13.12: Inside the womb (doc-12467)

13.12 Review

13.12.1 Study checklist

Cell division

- give examples of organisms that reproduce by binary fission 13.2
- **describe** mitosis 13.2
- **outline** some reasons why cells need to divide 13.2

Cancer research

- **define** the terms ‘cancer’, ‘tumour’, ‘malignant’ and ‘benign’ 13.3
- **outline** the cause of skin cancer and describe some strategies to reduce your risk of skin cancer 13.3
- **outline** examples of current scientific research aimed at addressing health issues 13.3

Plant structure and function

- **describe** the structure and function of plant roots 13.4
- **describe** the structure and function of plant stems 13.4
- **distinguish** between xylem and phloem tissue 13.4
- **describe** the structure and function of leaves 13.5
- **outline** the role of stomata in plant leaves 13.5

Photosynthesis

- **recall** the word equation for photosynthesis 13.5
- **explain** why plants need to photosynthesise 13.5
- **interpret** the results of experiments relating to photosynthesis 13.5
- extract information from a timeline outlining some of the research carried out to investigate photosynthesis 13.5

13.12.5 Science investigation skills

- design, carry out and write a report about a scientific investigation involving seed germination or plant growth **13.8**
- **distinguish** between independent, dependent and controlled variables **13.8**

13.12.6 Reproduction

- **contrast** sexual and asexual reproduction **13.2**
- **describe** fertilisation **13.6, 13.9, 13.10**
- **contrast** internal and external fertilisation **13.9**
- **recall** the names and functions of the parts of flowers **13.6**
- **describe** the life cycle of flowering plants **13.6, 13.7**
- **recall** the names and functions of the organs of the male and female human reproductive systems **13.10**
- **explain** the role of the placenta **13.11**
- **outline** some changes that occur to a fetus as it develops inside the womb **13.11**
- **describe** the birth process in humans **13.11**

Individual pathways

ACTIVITY 13.1
Revising growing and multiplying
doc-10577

ACTIVITY 13.2
Investigating growing and multiplying
doc-10578

ACTIVITY 13.3
Investigating growing and multiplying further
doc-10579

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FOCUS ACTIVITY

online only

Create a picture book for a 9- or 10-year-old child that explains where babies come from. Use language that the child would understand, and make sure the text and images are age appropriate.

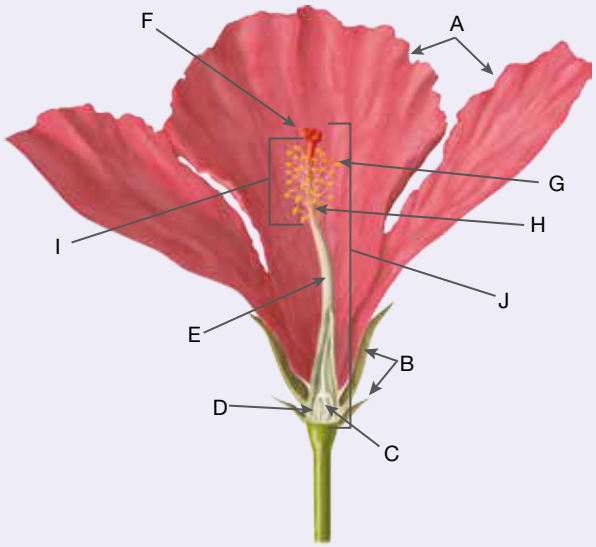
Access more details about focus activities for this topic in the Resources tab (doc-10576).

13.12 Review 1: Looking back

assessON

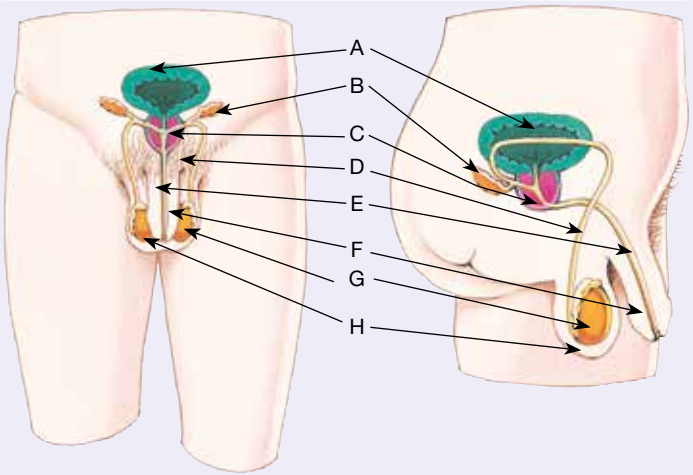
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

1. **Recall** how bacteria reproduce.
2. **Outline** two reasons why mitosis occurs in the human body.
3. After a series of medical tests, Betsy's mum was told that she had a benign tumour in her brain. **Explain** what is meant by a benign tumour and **justify** why the tumour may need to be removed despite being benign.
4. Making advances in the prevention, detection and treatment of cancer are important goals for science. Give two examples of recent developments in this area of scientific research.
5. Write a word equation for photosynthesis.
6. **Recall** what happens to the sugars made in photosynthesis.
7. Write down in your notebook which letter in the following diagram corresponds to each of these terms.
   ovules, sepals, filament, style, stigma, ovary, anther, petals, stamen, carpel

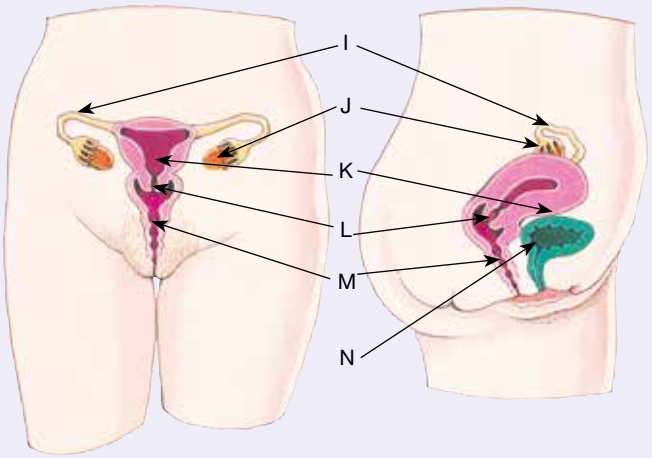


8. **Define** the following terms in your own words.
   gamete, amniotic fluid, zygote, placenta, fetus, embryo, ovulation, fertilisation
9. (a) **Identify** the parts labelled A–N in the diagrams below.
   (b) Write the functions of the parts labelled B, D, F, G, H, J, K and M in the diagrams below. Present your answers in a table.

The male reproductive system



The female reproductive system

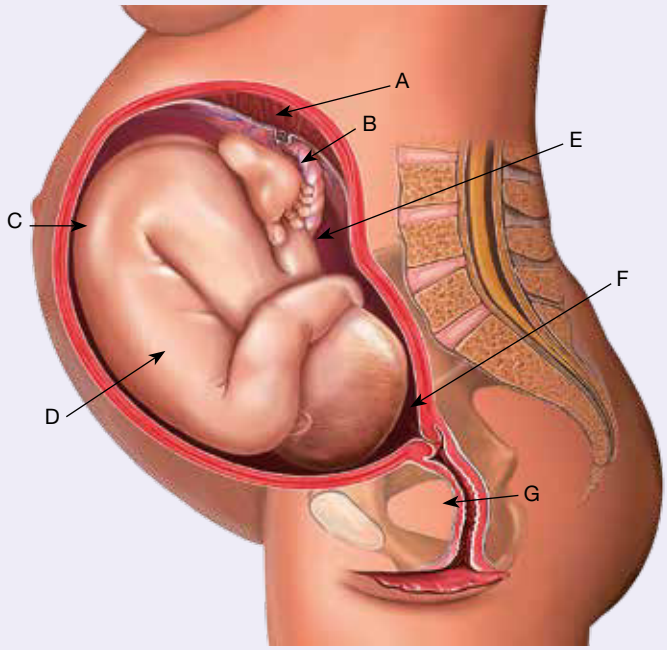


10. Charlotte wanted to find out if temperature affects the growth of plants. She bought four seedlings. She put one seedling in the fridge and one in her garage (which has no windows so is dark and cooler than her house). She put the third seedling on the windowsill (in full sun) and the fourth seedling on her desk (out of the sun but in daylight). Charlotte measured the height of each seedling every day for 10 days. Her results are shown in the table below.
    (a) Write an aim for Charlotte's experiment.
    (b) Suggest three improvements to Charlotte's experiment.
    (c) Graph Charlotte's results.
    (d) Write a conclusion for this experiment.

Heights (cm) of seedlings

Position	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
Fridge	5.0	5.5	6.0	6.2	6.6	7.0	7.3	7.5	7.7	8.0
Garage	5.0	5.6	6.2	6.6	7.0	7.3	7.6	7.9	8.4	8.8
Windowsill	5.0	6.0	6.7	7.5	8.0	8.5	9.0	9.6	10.2	10.6
Desk	5.0	5.8	6.3	7.0	7.5	8.0	8.5	9.1	9.6	10.0

11. Decide which of the following statements are true or false, and **explain** why.
    (a) Sexual reproduction results in offspring that are identical to their parents.
    (b) Humans are the only animals to undertake sexual reproduction.
    (c) When a male gamete and a female gamete fuse, a zygote is formed.
12. Label the parts A–G in the diagram at right.
13. **Explain** the following phrases or words in the context of the birth of a baby.
    (a) The cervix dilates
    (b) The water breaks
    (c) Contractions
14. Draw lines to match the entries in the table correctly.



Developmental stages of human embryo/fetus

Stage	Typical developmental indicators
20 weeks	Has fine eyebrows and all internal organs are now fixed in their final position
36 weeks	Weighs about 120 g; has a unique fingerprint
8 weeks	About 25 cm long, with hair forming on head
16 weeks	About 50 cm long and more often than not is now head down in the mother's pelvis
24 weeks	About 3 cm long, with tiny, developing limbs

15. What is the difference between asexual reproduction and sexual reproduction? Give examples.
16. **Explain** what processes each of the following organisms use to reproduce asexually.

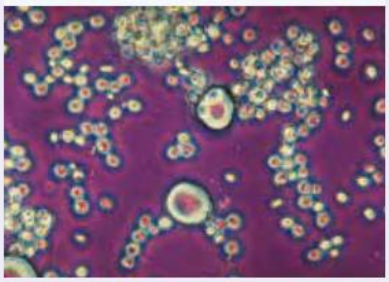
Flatworm



Mexican hat plant (*Bryophyllum diagremontianum*)

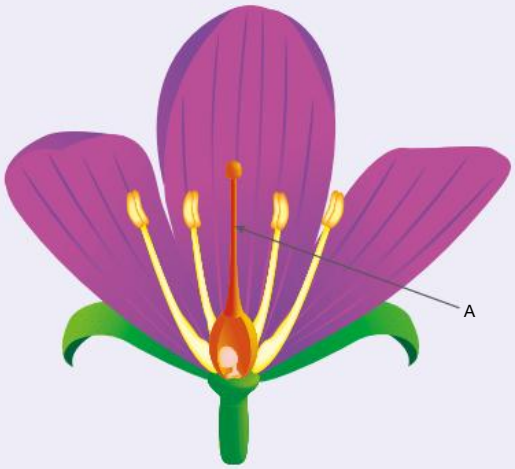


Magnified baker's yeast



Test yourself

1. Which of the following statements is correct?
   (A) Water moves up and down the stem of a plant in the xylem tubes.
   (B) Phloem tissue takes sugars from the roots to the leaves of plants.
   (C) Phloem tissue takes water from the leaves to other parts of the plant.
   (D) The movement of water from the roots to the leaves occurs in xylem tubes. **(1 mark)**
2. What is the name of the part labelled A in the diagram below?



   (A) Stamen
   (B) Style
   (C) Stigma
   (D) Ovule **(1 mark)**
3. Which of the following flow charts shows the stages of the life cycle of a flowering plant in the correct order?

A
- Flower formation
- Pollination
- Fertilisation
- Fruit formation
- Seed dispersal
- Germination
- Growth

B
- Flower formation
- Fertilisation
- Pollination
- Fruit formation
- Germination
- Seed dispersal
- Growth

C
- Growth
- Flower formation
- Fertilisation
- Pollination
- Fruit formation
- Germination
- Seed dispersal

D
- Germination
- Growth
- Flower formation
- Seed dispersal
- Fruit formation
- Pollination
- Fertilisation

4. Which of the following is NOT an example of asexual reproduction?
   (A) A shrub that is grown from a cutting of another shrub
   (B) Sowing the seeds of bean plants that have been collected during the previous year's harvest.
   (C) A garlic plant that is grown from one of several bulbs that are produced by another garlic plant
   (D) Growing an African violet plant from the leaves of an existing plant **(1 mark)**
5. Which of the following shows the correct sequence?
   (A) fertilisation → ovulation → implantation → zygote divides to form a blastocyst → placenta forms → growth and development → birth
   (B) implantation → fertilisation → zygote divides to form a blastocyst → placenta forms → ovulation → growth and development → birth
   (C) ovulation → implantation → fertilisation → growth and development → zygote divides to form a blastocyst → placenta forms → birth
   (D) ovulation → fertilisation → zygote divides to form a blastocyst → implantation → placenta forms → growth and development → birth **(1 mark)**
6. Use your knowledge of plants to **explain** the following.
   (a) It is possible to grow plants without soil (hydroponically) as long as certain nutrients are added to the water. **(1 mark)**
   (b) Some farmers find that their orchards produce more fruit if there are beehives near the orchard. **(1 mark)**
7. Variegated leaves are green in some parts and yellow in other parts. The yellow parts of the leaves do not contain chlorophyll. **Predict** whether photosynthesis would occur in the yellow parts of the leaves. **(3 marks)**

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Complete this digital doc: Worksheet 13.13: Reproduction puzzle (doc-12468)

Complete this digital doc: Worksheet 13.14: Plants puzzle (doc-12469)

Complete this digital doc: Worksheet 13.15: Reproduction summary (doc-12470)

Complete this digital doc: Worksheet 13.16: Plants summary (doc-12471)

TOPIC 14
Earth's precious resources

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?

Australia is rich in resources, including coal, natural gas, oil, iron, copper, uranium and a host of precious minerals. But Australia is sadly lacking in the most precious resource of all — water. All of our resources — fuels, precious minerals and water — must be used wisely to ensure that our future is sustainable.

LEARNING SEQUENCE

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Hot liquid iron being poured from a melting pot



Thinking about the Earth's resources

The term **natural resources** describes the naturally occurring raw materials that we use to make, consume and export products and to provide useful energy. These resources include fossil fuels, such as coal, oil, natural gas, minerals and timber. Some natural resources are essential just to keep us and almost all other living things alive, including water, sunlight and gases such as oxygen in the atmosphere. Natural resources can be broken down into two main categories — those that are renewable and those that are non-renewable.

1. As a group, discuss the difference between renewable and non-renewable resources. Then decide whether each of the following natural resources is renewable or non-renewable.
   - Coal
   - Hydro-electricity
   - Natural gas
   - Water
   - Oxygen
   - Wind energy
   - Timber

   After making your decisions, copy and complete the table below. Then compare your competed table with those of other groups.

Natural resource	Renewable or non-renewable?	Reason for your decision	Why is it useful?
Coal			
Hydro-electricity			
Natural gas			
Water			
Oxygen			
Wind energy			
Timber			

Wind energy is the natural resource that drives these wind farm turbines.



2. Aboriginals and Torres Strait Islanders have always used natural resources as medicine and to make tools and paint.
   (a) List the natural resources used for each of these purposes.
   (b) Suggest other purposes for which these natural resources were used.

To mine or not to mine?

Imagine it is the year 2070 and the last deposit of oil that mankind can get to is deep beneath the Great Barrier Reef. If the oil is extracted, there will be enough oil products to keep cars on the road for another ten years. However, to reach the oil, the Great Barrier Reef would be completely destroyed, never reforming. What would you do? Justify your answer.



14.2 Nature's resources

14.2.1 Renewable or non-renewable?

The Earth's crust contains a vast range of natural resources that are used to make things that we take for granted every day; buildings, furniture, cars and plastics (including polyester and nylon) are just a few examples. It also provides the resources used to make fuels such as petrol, natural gas and coal.

Renewable resources are those, such as timber and water, that replace or renew themselves. Sunlight is also a renewable resource because it is continually being replaced by the sun. Non-renewable resources are those that cannot be replenished or that take millions of years to replace themselves. Supplies of non-renewable resources will eventually be exhausted with continuous use.

So why are fossil fuels and minerals considered non-renewable? Well, to answer that we really need to look at how they came into being in the first place.

Fossil fuels

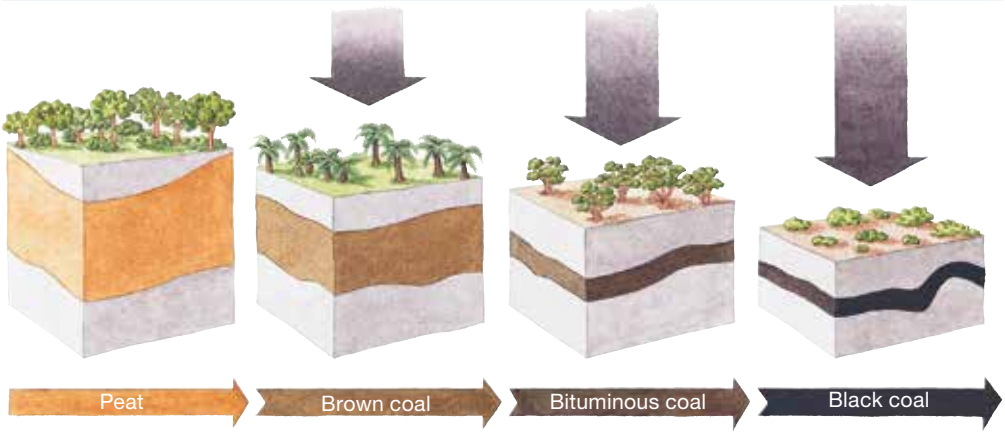
The energy stored in **fossil fuels** comes from the remains of ancient plants and animals, buried under layers of the Earth's crust that have built up over tens or hundreds of millions of years. When we burn fossil fuels — coal, oil and natural gas — the stored energy is converted to other forms of energy, including heat, movement and light.

From plant matter to coal

Just over 250 million years ago, ferns and other plants dominated the Australian landscape. As the plants died, they formed thick layers of rotting materials on the forest floors and in swamps. Under pressure from the layers above, the material turned into **peat** — a soft, dark, rotting mass. About 250 million years ago, the Australian landscape went through many changes. Sea levels fell and rose again, and sediments were deposited on top of the layers of peat.

Heat and pressure from the layers of sediment above turned the peat into brown coal (**lignite**). Further heat and pressure turned lignite into **bituminous coal** and, eventually, black coal (**anthracite**). The black coal found in parts of New South Wales and Queensland was formed this way. Younger lignite, found in Victoria, is less than 60 million years old. It has not been exposed to heat and pressure for as long as the black coal.

How coal forms



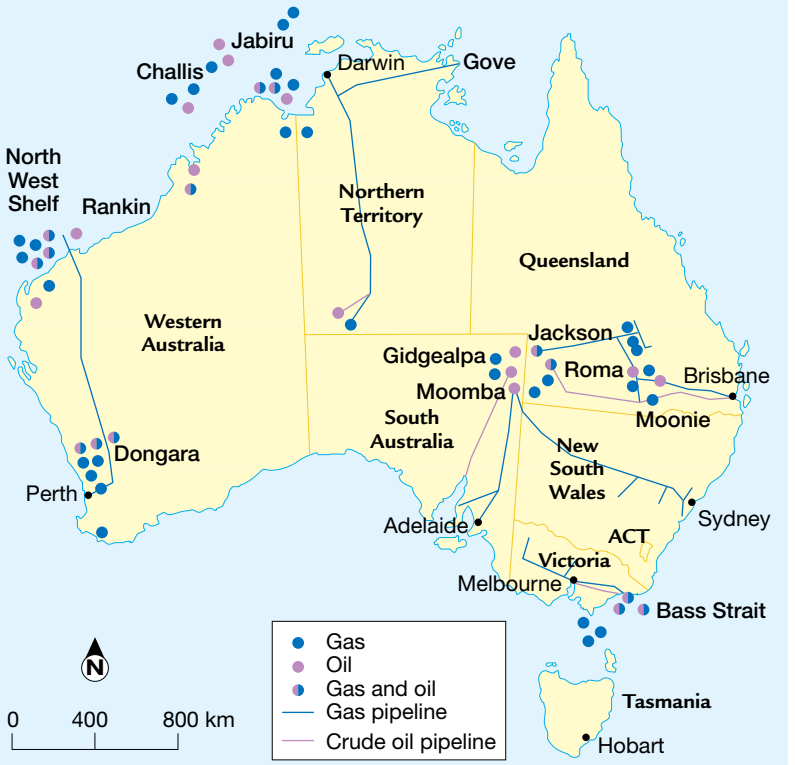
14.2.2 Oil and natural gas

Oil and gas are fossil fuels that formed from the remains of tiny sea animals and plants. Millions of years ago, the remains were buried on the ocean floor among other sediments. After millions of years of squeezing and heating, the sediments formed sedimentary rocks. Chemical reactions within the rocks slowly changed the remains of the sea organisms into oil and natural gas.

Rocks such as sandstone and limestone, which often form in old seabeds, are **porous**. Porous rocks are full of tiny holes. This means that other substances can seep through them. Oil and gas formed in porous rocks can seep through and start to move upwards. The oil and natural gas continue to move up until they are stopped by a layer of non-porous rock.

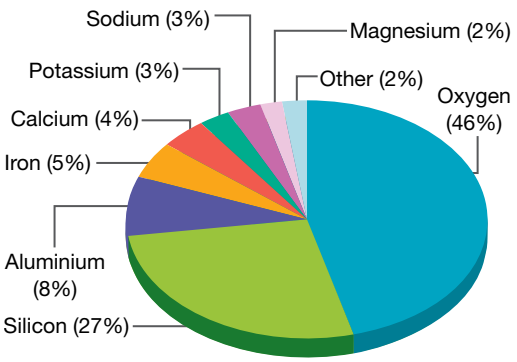
Scientists who search for oil and natural gas look for non-porous rocks in layers above porous rocks. They also search for layers that have been folded or faulted. The folds and faults create traps where the oil and natural gas can collect.

Central Australian oil and gas is about 100 million years old. Scientists believe it formed from the remains of organisms that lived in the Eromanga Sea, which once covered inland Australia.

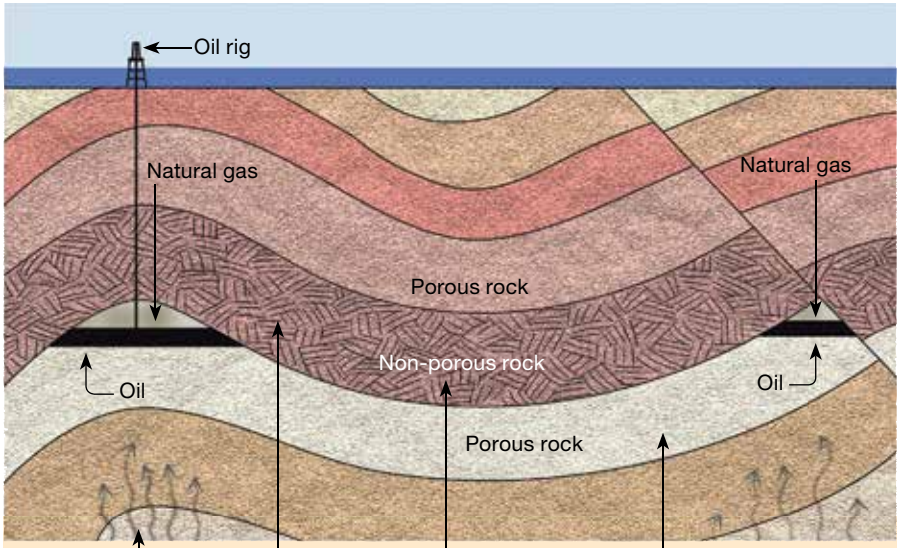


14.2.3 Mineral sources

We use the word **mineral** to describe chemical elements or compounds that are formed by geological processes. Mineral compounds are made up of different combinations of elements.



There are 92 naturally occurring elements found on the Earth; however, they are not all found in the same concentration on the Earth's surface. When the Earth's crust began to form from molten rock billions of years ago, the lighter elements such as oxygen rose to the top layers of the mantle and the crust, while heavier elements such as iron sank towards the Earth's core. As a result of this separation, three-quarters of the Earth's crust is made up of silicates (compounds of silicon and oxygen) while the elements that we are most interested in — generally metals — have been left behind only in low concentrations. The pie chart at right shows that, out of the 92 naturally occurring elements, 98 per cent of the Earth's crust is made up of only 8 of them.



Source rock
The rock where the oil forms is called the source rock. It is a porous rock that allows the oil and gas to seep through.

Fold
Folded and faulted rocks trap oil and natural gas.

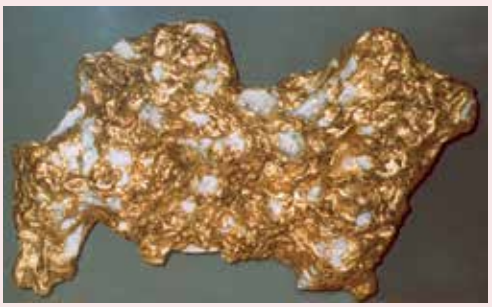
Non-porous rock
Oil cannot seep through non-porous rocks such as shale.

Reservoir rock
The rocks where oil and natural gas are found are called reservoir rocks. Oil companies drill through the non-porous rocks above to reach the oil and gas reserves. Natural gas bubbles out of the oil to form a separate layer above the oil.

Most of the metal elements are chemically combined with oxygen, silicon or other non-metallic elements within minerals, with only a few rare metals such as gold and platinum being found in their pure form in nature.

HOW ABOUT THAT!

The largest gold nugget ever found was called 'The Welcome Stranger'. It was discovered (or uncovered, really) by John Deason and Richard Oats on 5 February 1869 in Moliagul, Victoria. The Welcome Stranger is 61 cm long, 31 cm wide and weighs a whopping 71 kilograms!



Like their parent elements, minerals are not evenly distributed throughout the Earth's crust. Instead, the same geological processes that shaped the Earth's crust to form mountains, gouge out rivers and separate continents, also caused specific minerals to accumulate in some regions. Geologists call these regions with high concentrations of minerals **ore bodies**.

Apart from large amounts of brown and black coal, Australia benefits from having many large ore bodies that provide us with minerals as varied as rutile, zircon, nickel, uranium, zinc, lead, antimony, bauxite, copper, gold, iron ore, industrial diamond, ilmenite, lithium, manganese ore, niobium, silver and tantalum. It is important to remember, however, that, while there is a huge amount of mineral wealth in the Earth's crust, the amount is finite. No new mineral resources are created to replace what we take from the ground — at least, not in humanity's lifetime. To find out more about Australia's natural resources using interactive explorations, use the **Down to Earth** weblink in the Resources tab.

14.2 Exercise: Remember and think

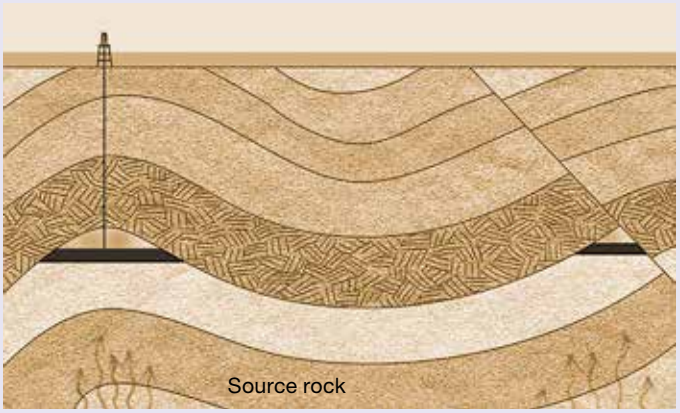
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Recall** why resources such as timber and water are often called renewable resources.
2. **Describe** what types of organisms scientists believe formed:
   (a) coal
   (b) oil and natural gas.
3. Apart from its colour, **explain** how black coal is different from brown coal.
4. **Distinguish** between source rock and reservoir rock.
5. **List** nine metals found in ore bodies in Australia.
6. **Recall** how an ore is different from other bodies of rock.
7. **Explain** why it is important to use mineral resources wisely.

Think

8. **Explain** why the fossil fuels and minerals in the Earth's crust are classified as non-renewable resources.
9. The most common element in the Earth's crust is oxygen. This element is a gas except at extremely low temperatures. In what form is the element found in the Earth's crust?
10. In the diagram below which rocks are likely to be porous and which are likely to be non-porous? **Explain** your answer.



Investigate

11. Aboriginals and Torres Strait Islanders used plants to treat illnesses, sores and ulcers. Find out which plants they used and what they were used for. Use a two-column table with the headings 'Plant' and 'Use' to present your findings.

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Complete this digital doc: Worksheet 14.1: Natural resources (doc-12472)

Explore more with this weblink: Down to earth

14.3 Extracting fossil fuels

14.3.1 At the coal face

Depending upon the location, volume and type of fossil fuel being mined, a variety of different methods is used to extract coal, natural gas and oil from the Earth's crust.

When a coal seam lies fairly close to the surface — up to a depth of a few hundred metres — the **open-cut mining** method is used.

Rock, soil and vegetation (the overburden) are first removed by bucket wheel excavators to expose the coal seam. Electrically powered bucket-shaped excavators load the mined coal onto conveyors, which transport it to the power-station boilers.

When the coal seam is deeper, it must be mined underground. However, underground mining is more costly than open-cut mining. For this reason, brown coal is not mined underground as its lesser efficiency as a fuel does not make it worth the extra cost.

Underground mining is also quite dangerous. As well as the threat of cave-ins and flooding, coal seams contain poisonous methane gas. Another poisonous gas, carbon monoxide, is also often produced when explosives are used underground. The dust produced by the coal not only damages miners' lungs, but also forms an explosive mixture with methane gas. Proper ventilation systems in underground mines are needed to minimise these dangers.

An open-cut mine



A bucket-wheel excavator at Yallourn can remove 2300 tonnes of brown coal in one hour.



HOW ABOUT THAT!

Almost one-quarter of the crust that makes up the Australian continent contains coal of one type or another. Australia has approximately five per cent of the world's known reserves of black coal and approximately 16 per cent of the world's known reserves of brown coal.

14.3.2 The search for oil and gas

Oil and gas exploration is difficult, expensive and uncertain. It involves searching for the right combinations of sedimentary rocks, folding and faulting.

Most of Australia's oil is found **off-shore** under the seabed of Bass Strait and under the North West Shelf on the Western Australian coast. When a reserve of oil and gas is found, a platform is built over the area to be drilled. The platform houses all of the drilling equipment and often has accommodation for the people who work on the rig.

Once drilling has exposed the oil and gas, pipelines are installed and used to transport the oil and gas to refineries, ready for processing.

The oil taken from beneath the Earth's surface is converted in oil refineries into a number of different fuels

Oil rig off the coast of South Australia. Oil companies drill down through the layers of rock to tap oil reserves.



Australia's oil and gas reserves

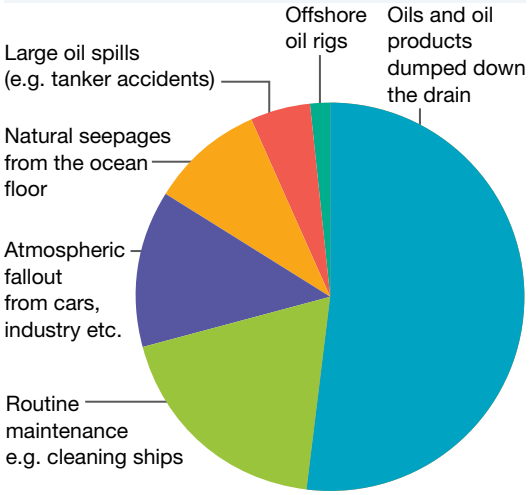


(such as diesel fuel, petrol and kerosene) and other products. Natural gas is mainly used for heating and for cooking. To learn more about how oil rigs work and how oil is found use the **Oil rigs** weblink in the Resources tab.

14.3.3 Coastal pollution

Oil from offshore oil rigs, oil spills and natural seepages contribute to coastal pollution. However, the graph at right shows that most pollution comes from the oil and oil products that are disposed of down our drains.

Sources of coastal pollution



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. **Distinguish** between open-cut and underground mining.
2. **Recall** what is meant by the term 'overburden'.
3. **Explain** why brown coal is not mined underground even though there are seams below the surface that could be mined in that way.
4. **Recall** why the underground mining of coal is so dangerous.

Think

5. In power stations, coal is ground into a fine dust before it is burnt. **Explain** why this is done.
6. If wood is a renewable resource, **deduce** why many people are so concerned about the use of natural forests for wood products and paper.
7. **Explain** why it is possible to describe fossil fuels as stored solar energy.

Investigate

8. **Investigate** and report on how the process of 'fracking' is used to obtain natural gas and **explain** why it is controversial.
9. **Summarise** the benefits and disadvantages of extracting coal seam gas.

Create

10. Black lung disease is notorious among coal miners. Research this disease and find out what it is, who it affects, what its symptoms are and how it is treated. **Construct** a poster to display your findings.
11. Use the **Methane explosion** weblink on the Resources tab to read about a methane gas explosion in a Polish mine.

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Explore more with this weblink: Oil rigs

Explore more with this weblink: Methane explosion

14.4 Using fossil fuels

14.4.1 Coal as a fuel

Imagine a world with no fossil fuels. Sure, you think that just means no petrol for cars and no coal for power stations, so no electricity. But I bet you didn't realise that, without fossil fuels, there'd be no enamel paint, nail polish, Vaseline or plastics either! Even things like bitumen roads and tarmacs wouldn't be possible.

More than three-quarters of the black coal mined in Australia is exported. Most of the remainder is used to generate electricity in power stations. Some of the black coal is used in the production of steel and as briquettes for heating. The majority of Australia's brown coal mines are in Victoria, where most of the coal is used to generate electricity.

Black coal provides more energy than the same amount of brown coal, mainly because it contains less water. In some countries peat is used as a fuel. However, it has to be dried first. In Ireland, where there is very little coal or oil, peat is used to generate electricity.

Liquid fuel

The oil obtained from the ground, known as crude oil, is a sticky, dark, smelly mixture of chemicals called **hydrocarbons**. Methane, propane, butane and octane are all examples of hydrocarbons. All hydrocarbons are compounds of the elements hydrogen and carbon. The table below lists a range of hydrocarbons.

Examples of hydrocarbons

Hydrocarbon	Chemical formula	Carbon atoms in each molecule
Methane	CH_4	1
Ethane	C_2H_6	2
Propane	C_3H_8	3
Butane	C_4H_{10}	4
Octane	C_8H_{18}	8
Eicosane	$C_{20}H_{42}$	20
Triacontane	$C_{30}H_{62}$	30

Atoms can join or bond together in different ways. In some substances, atoms are joined together in groups called molecules.

Most of the useful products of crude oil are mixtures of different hydrocarbons. They include:

- petroleum gases, including methane, ethane, propane and butane. All of these gases can be used as fuels. Propane and butane are used in gas bottles for cars, gas stoves, caravans and barbecues.
- gasoline, which contains hydrocarbons with five to ten carbon atoms in each molecule. Gasoline is used as motor vehicle fuel and to make plastics and detergents.
- naphtha, which contains hydrocarbons with eight to twelve carbon atoms in each molecule. Naphtha is used in motor vehicle fuel, plastics, pesticides, fertilisers and in the processing of rubber.
- kerosene, which contains hydrocarbons with ten to sixteen carbon atoms in each molecule. Kerosene is used in aviation fuel, paint solvents, and paraffin for heating and lighting.
- diesel oils, which contain hydrocarbons with fourteen to twenty carbon atoms in each molecule. Diesel oils are used in fuel for trucks, trains, cars and domestic oil heaters, and for asphalt production.
- heavy crude oils, which contain hydrocarbons with more than twenty carbon atoms in each molecule. They can be separated into lubricating oils, petroleum jelly, candle wax and bitumen.

HOW ABOUT THAT!

The natural gas that we use as a fuel is a highly flammable mixture of hydrocarbons (mainly methane). A leakage is extremely dangerous as a spark or naked flame could cause a fire or explosion. Natural gas is also colourless and odourless. Chemicals are added to natural gas so that it smells. Otherwise, a leakage would be very difficult to detect until it was too late.



14.4.2 Fantastic plastic

Which material is strong, light in weight and cheap to make, comes in a huge range of colours and can be moulded into any shape?

It could only be one of the **synthetic** (manufactured) materials we know as **plastics** (a word derived from the Greek word *plastikos*, meaning 'able to be moulded'). Plastics are used to manufacture food containers and packaging, ballpoint pens, plumbing materials, car parts, rubbish bins, cling films like GLAD®Wrap and a multitude of other items.

Chemists also use the term 'plastic' to describe a property, or characteristic, of some materials. A plastic material is one that can be readily moulded into different shapes. Modelling clay is an example of a substance that shows this property. A disposable plastic spoon can be easily moulded into a different shape if it is heated gently in a hot drink.

Plastic is made in many colours and shapes for a huge range of uses.



14.4.3 Polymers

All of the synthetic materials we call plastics are **polymers**. Polymers are very large molecules that consist of many repeating units called **monomers**. Monomers are small molecules. Most monomers contain the element carbon. Polymer molecules may, therefore, contain thousands of carbon atoms. The other elements found in monomers and polymers include hydrogen, oxygen, chlorine, fluorine and nitrogen.

The chemical reactions that occur when polymers form can be modelled using plastic beads that clip together to form a long chain. Each plastic bead represents a single monomer molecule. The long chain, which may contain thousands of monomers, represents a polymer molecule.

Casein is a protein found in the milk of mammals. It is a polymer made up of many small molecules called amino acids. The prefix 'poly' (meaning 'many') is often used when naming polymers. For example, polyvinyl acetate (PVA) is a polymer made from the monomer known as vinyl acetate. In the same way polystyrene, which you may know as the 'coolite' used to insulate eskies, is made up of linked chains of styrene monomers. To find out more about polymers use the **Fantastic plastic** weblink in the Resources tab.

14.4.4 Polythene

Polythene (also called polyethylene or, more correctly, polyethene) is a soft plastic that is used to make cling film, squeeze bottles, milk crates and many other useful items. Depending upon how closely packed the ethylene monomers are, and how they are linked together, polythene can vary widely in how rigid it is, how well it resists chemical damage and how easily it can be recycled. Polythene was discovered by accident in 1933 when some oxygen leaked into a container, allowing the ethene monomers to join together rapidly.

Synthetic fibres

Until the development of nylon in 1938, the world relied almost completely on cloth made from **natural fibres** from plant and animal products such as wool, cotton, linen and silk. Today, natural fibres alone are insufficient to provide clothing for the world's population. A single chemical plant may produce as much polyester fibre in a year as 100 000 hectares of agricultural land planted with cotton.

The most widely used synthetic fibres today are **nylon** and **polyester**. These fibres are both polymers. The monomers that are used to produce nylon and polyester are derived from **petroleum** (crude oil). Synthetic fibres are made by pushing the softened plastic materials through small holes in a nozzle called a **spinneret**, which looks something like a small shower rose.

As the fine threads of polymer harden, they become long **filaments**. These may be spun together or combined with natural fibres to form cloth.

Polyester or nylon can be mixed with other fibres and woven on large industrial looms to produce cloth.



14.4.5 A new breed of fibres

When you watch the feats of Olympic athletes such as cyclists, skiers and skaters, it's almost certain that

they are wearing Lycra®. Lycra is not a fabric but the registered trademark of a synthetic fibre called spandex, a polymer derived from crude oil, which was invented in 1959. Spandex is lightweight, durable, retains its shape and fits snugly. It even pulls moisture away from the wearer's skin.

Spandex is very elastic. It can stretch to up to seven times its normal length and spring back to its initial length when released. Spandex is always blended with other fibres. As little as 2 per cent of this polymer in a blend changes the properties of the fabric. Lycra suits usually include between 3 and 10 per cent spandex.

Textile scientists are currently developing methods of producing spandex from corn and other food crops.

Lycra is used extensively in sport because of its light weight, tight fit and ability to pull moisture away from the skin.



14.4.6 Detergents

When you wash the dishes, it is obvious that water alone is not good enough. That's because the fats and oil in foods do not dissolve in water. You need to use detergents, which, when mixed with water, loosen or remove fatty and oily substances from surfaces. They can then be rinsed away by the action of running water or a wet cloth. Detergents are made from some of the hydrocarbons found in crude oil. Unlike detergents, soaps are made from natural fats and oils.

INVESTIGATION 14.1

Making nylon (teacher demonstration)

AIM: To demonstrate how nylon can be made

You will need:

aqueous 1,6-diamino hexane solution (hexamethylene diamine)
adipoyl chloride solution
two 100 mL beakers
glass stirring rod
tweezers

CAUTION: This experiment produces hydrochloric acid as a side product so it must be performed in a fume cupboard. Protective gear is needed. Care should be taken to avoid fumes and contact with skin.

- Pour the 1,6-diamino hexane solution into a clean 100 mL beaker.
- Slowly add the adipoyl chloride solution so that it sits in a layer on the top of the hexane solution rather than mixing. A film of nylon should form where the two solutions meet.
- Using a pair of tweezers, pull out a small string of the nylon and wrap it around a glass rod.
- As new nylon forms, continue to wind the nylon around the stirring rod.
- Wash the nylon thread thoroughly in a sieve and burst any bubbles that form. After rinsing and drying in air, the nylon can be handled safely.

Discussion

1. Describe the appearance of the fibre formed in the demonstration.
2. What do you think would have happened if the two liquids had been allowed to mix together completely?
3. Use a piece of the fibre produced, and compare it with a similar length of commercially available nylon thread or fishing line.

HOW ABOUT THAT!

In 1992, scientists in the USA found a way to grow plastic. The plastic was produced in small amounts by mustard plants after genetic engineers added the genes of a type of soil bacteria to the plants. These bacteria were able to produce granules of a natural polymer called polyhydroxybutyrate (PHB). This polymer is very similar to the one called PET (polyethylene terephthalate), which is used to make soft-drink bottles. Unlike synthetic plastics, PHB is biodegradable; that is, it can be broken down by microbes after it is thrown away.

In the not too distant future, plastic as we know it will be replaced by biodegradable plastics that can be grown from genetically modified plants like the *Brassica napus* (rapeseed) shown below.



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. **Recall** the main uses of black coal and brown coal in Australia.
2. **Explain** why peat has to be dried out before it is used as a fuel.
3. **Recall** what a hydrocarbon is.
4. **Recall** the names of five hydrocarbons found in crude oil and write the chemical formula for each one.
5. **Recall** two uses of each of the following components of crude oil.
   (a) Petroleum gases
   (b) Gasoline
   (c) Naptha
   (d) Kerosene
   (e) Diesel oils
   (f) Heavy crude oils
6. **Explain** why pure natural gas would be a very dangerous fuel.
7. **Distinguish** between a natural and a synthetic fibre.
8. **Recall** three examples of a synthetic fibre.
9. **Explain** how synthetic fibres such as nylon are manufactured.
10. **Recall** the meaning of the term ‘plastic’.
11. **Define** the term ‘polymer’.
12. **Recall** which element is contained in most monomers and polymers.

13. **Recall** the fibre that all Lycra suits contain and describe the properties that make it useful.
14. **Explain** how detergents remove fatty and oily substances from surfaces.

Think

15. **Explain** why brown coal is used to generate electricity in Victoria rather than black coal, even though black coal provides more energy per kilogram.
16. **Identify** the natural resource found in the Earth's atmosphere that is essential for the burning of fossil fuels.
17. **Describe** some of the advantages that synthetic fibres have over natural fibres.
18. **Identify** the polymers formed from the following monomers.
    (a) Ethene
    (b) Vinyl chloride
    (c) Styrene
    (d) Propene
19. **Explain** why polyester is classified as a non-renewable resource while wool is classified as a renewable resource.

Imagine

20. Imagine if all the objects made from plastics suddenly disappeared. How would your life be changed? Write an imaginative piece **describing** this. You may wish to talk to someone over the age of 70 about life before plastics.

Investigate

21. **Investigate** and report on how the different components of crude oil are separated from each other in a fractionating tower.
22. Design an experiment to compare the strength of plastic supermarket bags with the strength of other types of bag. Ensure that your tests are 'fair tests'.

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Complete this digital doc: Worksheet 14.2: Separating crude oil (doc-12473)

Complete this digital doc: Worksheet 14.3: PVC — friend or foe? (doc-12474)

Explore more with this weblink: Fantastic plastic

14.5 Make mine renewable

14.5.1 A question of responsibility

About 80 per cent of the world's energy needs are supplied by fossil fuels. In 2010, fossil fuels provided about 94 per cent of Australia's energy. Only 6 per cent is supplied by renewable energy sources. The federal government has set a target of at least 20 per cent of Australia's energy supply being from renewable sources by the year 2010.

Most power stations on mainland Australia rely on coal to drive the **turbines** used to generate electricity. The problems caused by using a fossil fuel such as coal, including pollution and global warming, give us no choice but to look for alternative sources of energy. Governments, industry and power companies all have a responsibility to seek renewable alternatives. Even you, as a consumer, have a responsibility to make sensible choices about your energy use. The first step is to be aware of the problems caused by using coal and of other options for generating electricity.

14.5.2 Renewable options

Solar energy

Solar energy can be used by photovoltaic cells like those used to power the telephone booth in the photograph opposite. Photovoltaic cells can also be used to power domestic hot water systems. Photovoltaic

cells transform light energy from the sun into electrical energy that can be used immediately or stored in rechargeable batteries.

Solar thermal power stations use curved mirrors that reflect sunlight onto tubes filled with oil. The hot oil is used to heat water to form steam, which drives the turbines that generate electricity.

A solar-powered payphone



14.5.3 Wind energy

Wind farms dotted with wind turbines can be found in many countries throughout the world, including Australia. A single wind turbine can provide enough energy to supply more than 700 average homes with the electricity they need. **Wind energy** is renewable because wind is caused by the uneven heating of the Earth and its oceans by energy from the sun.

14.5.4 Biomass

Biomass is a renewable fuel produced by the remains of living things. Dead and rotting plant and animal tissue produces gases such as methane, methanol and oils that can be used as fuels to drive small turbine electricity generators. Some small biomass electricity generators already exist in rubbish tips.

Ocean waves

The energy of ocean waves has been used to generate electricity on a wave 'farm' in Portugal since 2008. The up and down movement of the waves is used to drive motors that generate electricity. **Ocean wave energy** is renewable because the waves are produced by the effect of the wind on the ocean.

Tidal energy

The energy of rising and falling tides is used in several power stations worldwide. Reversible turbines are placed at the entrance to a bay in areas with extremely high and low tides. Water moving into and out of the bay drives the turbines as the tide changes. Tides are caused by the gravitational pull of the moon and the sun, so **tidal energy** is renewable.

Geothermal energy

The term 'geothermal' comes from the Greek words *geo*, meaning 'of the Earth', and *therme*, meaning 'heat.

In parts of New Zealand and Iceland, energy transferred from rocks just below the Earth's surface is used to turn water into steam and drive turbines in geothermal power stations. Other countries that use **geothermal energy** include the United States and Japan.

Hydro-electricity

About 5 per cent of Australia's electricity is generated by **hydro-electric** power plants. This is a renewable energy source because it depends on solar energy and water. Heat from the sun evaporates water from the oceans. Clouds are formed and it eventually rains. The turbines in hydro-electric power stations are turned by water falling through pipes from very high and large dams.

14.5.5 The nuclear energy option

Nuclear power stations use energy released from the radioactive metals uranium or plutonium to boil water to produce the steam that drives turbines to produce electricity. **Nuclear energy** is a non-renewable energy source. Most of the world's nuclear power stations can be found in the United States, Europe, Japan and Canada.

In a hydro-electric power station the turbines are driven by water falling through pipes from a high dam.



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. How much of Australia's energy will be supplied by renewable energy sources in 2020, according to the target set by the federal government?
2. List two ways of ensuring that the Earth's supply of non-renewable energy resources doesn't run out.
3. **Describe** two ways in which solar energy can be used to generate electricity.
4. **Identify** a non-renewable fuel that is not a fossil fuel.

Think

5. The turbines in coal-fired and hydro-electric power stations rotate in only one direction. Why are the turbines in tidal power stations reversible?
6. Which renewable energy options involve the use of heat from the sun? (*Hint:* There is more than one answer.)
7. Nuclear energy is a non-renewable energy source.
   (a) Why is it classified as non-renewable?
   (b) Is nuclear energy a fossil fuel? **Justify** your answer.
8. Most of the methods of generating electricity involve the use of turbines. Into what form of energy do turbines convert the energy of steam, falling water and other energy resources?
9. Each of the renewable energy options for generating electricity solves some of the problems caused by burning fossil fuels. However, each of them also has disadvantages. **Describe** the disadvantages of each of the renewable energy options.

Investigate

10. Choose one of the renewable energy options or nuclear energy and research it in more depth. Write a report, using diagrams where necessary, to show how this form of energy is used to generate electricity.

14.6 Mining for metals

14.6.1 Ores

Minerals containing metals of value are called **mineral ores.** It takes a lot of time, effort and money to get the rocks that contain the mineral ores out of the ground, separate the mineral ores from the rock and extract the metal element from the mineral ore. The **mining** of a mineral ore can take place only if enough of it is found at a single location.

The mining industry makes a major contribution to Australia's economy. Apart from the profits that go to shareholders in mining companies and to the government in taxes, the mining industry employs many thousands of Australians. Scientists and engineers are involved at every stage of the mining process.

Mineral exploration

Geologists make use of satellites equipped with cameras, radar and other sensors to search for geological features that are likely to contain high concentrations of minerals. Minerals in the crust dissolve in rain and running water and are washed into creeks and rivers. A chemical analysis of the sediments and surface water of lakes and streams, therefore, provides evidence of the presence of minerals in the area.

The magnetic properties of large bodies of rocks containing some minerals can be detected from aircraft or by geological surveyors on the ground. Samples of soil and rocks are taken using portable equipment. On average, only one in 1000 sites that are sampled is eventually mined.

If there is sufficient evidence of useful mineral deposits that might be worth mining, a licence must be obtained before any clearing is done or heavy drilling equipment is brought in. Helicopters are sometimes used to bring in heavy equipment to protect sensitive ecosystems. Drilling allows mining companies to have a detailed look at what lies beneath the surface. Mining companies are required by law to clean up exploration drill sites and ensure they are left as they were found.

Geological surveyors use simple equipment such as pick hammers to collect samples of rock.



Helicopters are sometimes used to bring heavy equipment into mines.



14.6.2 Taking out the mineral ore

In order to obtain mineral ore from the ground, it is necessary to remove large amounts of rock and soil. The way this is done depends on how close the mineral ore is to the surface. If it is close to the surface the vegetation and topsoil are removed. The waste rock removed from beneath the topsoil is called the **overburden**. The removed topsoil and overburden are used to fill areas that have already been mined, or they are left in a pile to restore the newly mined area when mining is completed. This method of mining is called **open-cut mining**.

If the mineral ores are deep below the surface, **underground mining** is undertaken. This method of mining is more dangerous and expensive than open-cut mining. Shafts and tunnels are dug up to four kilometres into the ground to reach the rocks containing the mineral ore.

The development of open-cut and underground mining is overseen by mining engineers. Mining engineers use scientific knowledge from a number of branches of science to design mines and the plants in which the metals of value are extracted. They are also involved in ensuring that damage to the environment is minimised.

INVESTIGATION 14.2

Searching without disturbing

AIM: To demonstrate the difficulty of finding mineral ores

You will need:

tray of sand
blindfold (optional)
paper and clipboard
10 paperclips
compass
ruler

- With a partner, draw two identical maps of the sand tray. Use the ruler to construct a grid on each map. The grids need to be labelled across the top and down the side (e.g. A–J across the top, 1–15 down the side) and should consist of at least 100 equal rectangles or squares.
- Without showing your partner, hide the paperclips in the tray of sand and mark the location of the 10 paperclips on your map.
- Your partner's task is to locate the 10 paperclips and mark them on the map without disturbing the sand. You might wish to set a time limit.
- Swap roles and repeat the previous steps.

Discussion

1. What property of the paperclips was used to locate them?
2. How could your predictions of the locations be checked with a pencil?
3. After checking, can the sand be restored to its initial condition?

14.6.3 Getting the metal

Obtaining the metal from the rock containing the mineral ore usually takes place in three stages.

1. **Mineral extraction**. The rock taken from the ground is a mixture of the mineral ore and waste substances such as sand and other unwanted minerals. These substances are called **gangue**. Mineral extraction involves crushing, grinding and washing the rock to separate the mineral ore from the gangue.
2. **Metal extraction** is the removal of the metal element from the mineral ore. This always involves chemical reactions. It often involves **smelting**, in which the mineral ore is melted. Smelting is used in the extraction of iron, copper and zinc ores. Extraction of aluminium from ore is achieved by **electrolysis** of molten aluminium ore. This involves passing an electric current through the molten ore. This is a very expensive process because of the amount of electrical energy needed. The high cost of aluminium extraction is one of the reasons that recycling of aluminium cans is so important.
3. **Purification** of the metal. The metal obtained from the extraction process still contains impurities. These are removed, leaving behind the pure metal. Copper and zinc are purified by electrolysis.

During the smelting process of copper, some of the impurities are removed from the mineral ore.



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. **Describe** the method of open-cut mining for removal of mineral ores from the ground.
2. Construct a two-column table. In the first column, list the three stages involved in obtaining a pure metal element after the rock containing its mineral ore is taken from the ground. In the second column, **describe** the purpose of each of the three stages.
3. **Define** the term 'gangue'.

Think

4. The most common single element in the Earth's crust is oxygen. This element is a gas except at extremely low temperatures. In what form is the element found in the Earth's crust?
5. **Explain** why helicopters are sometimes used instead of trucks to bring heavy equipment into mine sites.
6. List the branches of science that you would expect a mining engineer to have an understanding of in order to design mines and extraction plants.
7. Construct a two-column table. In the first column, compile a list of scientific and engineering experts that a mining engineer would consult during the design of a mine and extraction plant. In the second column, briefly **describe** the different tasks that each of the experts might assist with.

Investigate

8. Long before the big mining companies began exploring for and extracting minerals, Australian Aboriginals extracted a mineral called ochre from the ground.
   (a) **Investigate** and report on:
      (i) which chemical compound is found in all ochre
      (ii) how ochre was used by Australian Aboriginals
      (iii) how ochre was mined.
   (b) Suggest how the knowledge of mining possessed by Aboriginal and Torres Strait Islander peoples could be used to help in the management of natural resources in the twenty-first century.

Investigate and create

9. Construct a flow chart to show how one of the metals — copper, aluminium, iron or zinc — is extracted from the rock containing its mineral ore. **Identify** the parts of the extraction process that correspond to:
   (a) mineral extraction
   (b) metal extraction
   (c) purification.
   You will need to use the internet, a library or your own resources at home to gather information about your chosen metal.

14.7 Mining and the environment

14.7.1 The decision to mine

Mining provides metals that we can't seem to live without, provides the fuel used to generate electricity and creates great wealth for some Australians. Mining provides many jobs and brings Australia income, which helps maintain the high living standards of Australians.

However, some forms of mining leave scars on the face of the Earth by making big holes in the ground and removing vegetation. Mining can damage the habitats of animals and plants, pollute the water and air, and leave nasty-looking piles of waste soil and rock. Mining companies, just like individuals, are expected to be good citizens and responsible members of the community. The economic benefits of mining have to be balanced against the social and environmental responsibilities.

The development of mines to exploit the natural resources below the surface always causes arguments. The decision about whether mining should take place, or how it should take place in a particular location, is never a simple one.

Preparation of a waste rock dump before rehabilitation (Now turn the page.) © Xstrata Copper



14.7.2 To mine or not to mine?

To decide whether it will be profitable to mine and extract a metal, a mining company must consider:

- the amount of mineral in the ore body
- the selling price of the metal
- the costs involved in mining the mineral ore (this depends on the location and depth of the ore body)
- the cost of extracting the metal from the mineral
- the cost of minimising and repairing damage to the environment
- the intended use of the land when mining is completed
- any compensation that needs to be paid to the local population.

You can't start until …

In the past, mining was often carried out without considering its long-term effect on the environment and the people who live and work in the area. Today, however, an **environmental impact statement (EIS)** must be prepared before a mining operation can commence. This statement outlines how the mining company intends to manage all environmental aspects of the proposed mine. It also outlines how the land will be **rehabilitated** or reconstructed, so that it can be used again after the completion of the mining.

The environmental impact statement, along with any other relevant information, is studied by the government before permission to proceed is granted.

The EIS will report on:

- existing flora, fauna and soils
- existing towns and roads in the area
- proposed new towns, roads and other developments
- how the new development might affect the local community and environment
- alternative plans to complete the development that might have less impact on the environment
- measures that will be put in place to monitor and control air, water and noise pollution during the project and while rehabilitation is undertaken
- rehabilitation proposals for the area.

14.7.3 Rehabilitation

Before mining of a new site begins, seeds of the natural vegetation of the area are collected so that seedlings may be cultivated at a later stage. The seedlings are grown in special nurseries until they are mature enough to return to the site of the mine.

Progressive rehabilitation of the rock waste dump © Xstrata Copper



During open-cut mining, the overburden (the material removed from the site to expose the mineral ore or coal) is used to fill holes left from earlier stages of the mining operation. Fresh topsoil is used to cover the overburden to ensure that new vegetation will grow. The soil surface is shaped to fit in with the surroundings, fertilised and sown with seeds or planted with seedlings. Care is taken to shape the new surface to prevent the newly sown soil from being eroded or washed away by wind or rain.

Waste products

The waste products released as a result of some forms of mining can pollute air and water. Many mineral ores are compounds of the element sulfur. For example, the copper ore chalcocite is copper sulfide (Cu_2S) and the lead ore known as galena is lead sulfide (PbS).

One of the major pollutants released during the extraction of metals from their mineral ores is sulfur dioxide gas. Sulfur dioxide is also released during the burning of coal. Some of the sulfur dioxide released can be used to make sulfuric acid, which is used to make fertilisers and in industrial processes. The remainder is released into the atmosphere from towers up to 400 metres high. The high towers are used to spread the gas more widely into the atmosphere. The release of sulfur dioxide at ground level would endanger wildlife, people and property.

14.7.4 Acid rain

Sulfur dioxide reacts with moisture in the air to produce sulfurous acid (H_2SO_3) and sulfuric acid (H_2SO_4). When rain falls to the Earth carrying H_2SO_4 with it, it is called **acid rain**. Acid rain collects in streams, rivers and lakes, causing harm to animals and plants. It also damages buildings, bridges, statues and other structures. One of the major causes of acid rain in the Northern Hemisphere is the burning of coal with a high sulfur content in power stations. Australian coal has a very much lower sulfur content than the coal used in North America and Europe, and so acid rain is less of a problem here.

The solid wastes

The solid waste products of metal extraction are called **tailings**. The tailings are stored in tailings dams until they can be dried out and chemically treated to remove toxic chemicals. The tailings often contain small amounts of other valuable minerals that can sometimes be removed. In some cases, when a mineral extraction plant is near the sea, the tailings are discharged into the water.

When tailings are stored, some of the elements in them form acids that can dissolve in rainwater and leak into the ground. This leaking process is called **leaching**. The poisonous liquids can cause major damage to the surrounding environment and watercourses, endangering animals and plants.

Plants are grown over tailings dams to reduce leaching, and also to improve their appearance. This also helps to prevent the erosion of tailings material into streams or waterways nearby.

14.7.5 Learning from mistakes

The consequences of mining with little regard for the environment can still be seen at the town of Queenstown on the west coast of Tasmania. Copper mining and smelting began in the area in 1902. There was little control over the pollutants that were released into streams and the surrounding air. During the same period, extensive tree felling and bushfires almost cleared the land of vegetation. The polluted air prevented most new plant growth and rain washed away much of the topsoil. The entire site became barren and desolate.

Although smelting ceased in the 1960s, mining continued until 1994. Since then, Copper Mines of Tasmania has undertaken a major rehabilitation program to restore natural vegetation and minimise further damage to the environment. The most difficult task is to contain the leaching of tailings to protect waterways.

Queenstown, Tasmania



INVESTIGATION 14.3

Now it's your turn

AIM: To identify the benefits and disadvantages of mining

A large mining company proposes to mine uranium ore in an area surrounded by a large national park. It already operates a uranium mine and a treatment plant nearby. The company has provided an environmental impact statement that includes the points listed below.

- All mining will be underground. Approximately 25 per cent of the area required for construction will be rehabilitated immediately. When the mining operation ceases, the whole site will be rehabilitated.
- Radiation from the mine will be well below the internationally accepted safety levels, and there will be no risk to the local community.
- There will be no interference with areas of significance to the local Aboriginal people.
- The project will employ almost 300 people and boost the economy of the town closest to the mine.
- The local Aboriginal community will receive millions of dollars in royalties from the company.
- Worldwide production is not keeping up with the increasing demand for uranium in nuclear power stations.

The concerns already expressed by those opposing the mine include:

- The mining operation will affect the Aboriginal communities and the cultural heritage value of the area. A number of ancient pieces of Aboriginal rock art could be disturbed and affected by the amount of dust raised by the operation.
- The mine will be a visual eyesore, spoiling the national park and damaging the growing tourism in the area.
- Despite the assurances of the mining company that the radiation levels will not be dangerous, there is no guarantee that the employees, the environment and people who live nearby will not be affected by radiation.
- The clearing of land and the mine's operation will interfere with plant and animal life in the national park.
- The mining of uranium encourages the use of nuclear power stations to provide electricity. Uranium mining should be banned and the use of solar energy encouraged.

Discussion

1. Make a list of all the people or groups of people who might be directly affected by or interested in the proposed uranium mine and its impact.
2. Construct a table that lists all of the interested parties in a column running down the left side. Across the top of the table list each of the issues that need to be discussed (e.g. the environment, the economy). Then fill in the table by writing down how you think each interested party would feel about each of the issues raised.
3. Organise a forum within your class to debate whether the mine should go ahead. Each of the interested parties could be represented by one or more students.
4. Make a decision to either reject or accept the proposal to mine uranium in the area.

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.

Remember

1. **Recall** what an EIS is.
2. **Describe** what information an EIS includes.
3. **Explain** what is meant by the rehabilitation of land.
4. **Describe** how a mining company rehabilitates land used for mining.
5. **Identify** the major air pollutant released during the extraction of metals from their ores.
6. **Recall** what problem is created by coals containing high quantities of sulfur.
7. **Explain** why Australian coal is sometimes described as a 'clean' variety of coal.
8. **Recall** what tailings are.

Think

9. **Describe** what factors should be considered by a mining company when deciding whether to begin a mining project.

10. In a table like the one below, make a list of the benefits and disadvantages of mining.

Benefits	Disadvantages

11. **Explain** why an EIS is necessary before mining commences.
12. The recycling of metals, especially aluminium, is encouraged because of the amount of energy that can be saved. **Propose** some other arguments to support the recycling of metals.

Investigation

13. What is meant by 'sustainable development'? Use the internet to **Investigate** and report on statements made by large mining companies such as Rio Tinto and BHP Billiton about sustainable development.

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Watch this eLesson: Mining and Australia's environment (eles-0128)

Complete this digital doc: Worksheet 14.4: Mining and the environment (doc-12475)

Complete this digital doc: Worksheet 14.5: Acid rain (doc-12476)

14.8 Using metals

14.8.1 Versatile metals

More than three-quarters of the 92 naturally occurring elements are metals.

Most metals have the following useful properties. They are:

- malleable (can be beaten into a variety of shapes)
- ductile (can be drawn into a wire)
- good conductors of heat and electricity
- lustrous (shiny).

The strength and hardness of iron make it ideal for constructing buildings and machinery. Aluminium is light and malleable, making it suitable for use in cooking utensils, aircraft, boats and caravans. Tin, like aluminium, is very malleable but is very expensive because it makes up only about 0.001 per cent of the Earth's crust. Copper is a very good conductor of electricity and does not corrode as quickly as iron. Lead is very soft and heavy and can be easily beaten into shape. Chromium is very shiny when polished and is resistant to corrosion. Tungsten has a very high melting point and is hard, making it suitable for filaments in light globes and high-speed drill bits.

HOW ABOUT THAT!

Many civilisations, such as the ancient Roman Empire, prospered because they were able to develop better weapons than their enemies, using metals like iron.

The Roman gladius, a short iron sword, allowed the Roman legions to rule the Mediterranean world for over 400 years. The long shield was often used by groups of soldiers to form a protective wall and roof known as a testudo (tortoise) around themselves.



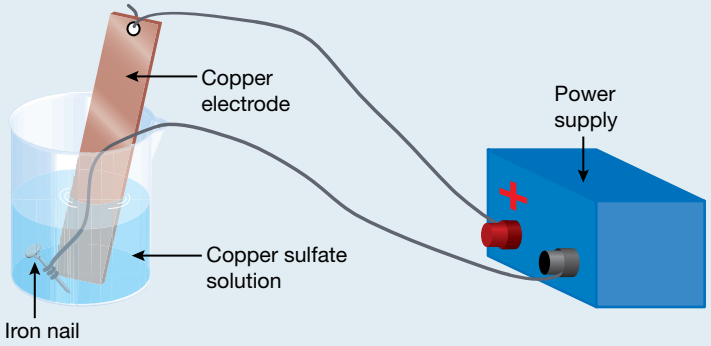
INVESTIGATION 14.4

Electroplating

AIM: To cover a metal with another metal

You will need:

250 mL beaker
copper electrode
clean iron nail
3 connecting wires
1M copper sulfate solution
6 volt power supply or battery



- Half-fill the 250 mL beaker with copper sulfate solution.
- Connect the circuit as shown in the diagram at right. The nail must be connected to the negative (black) terminal of the power supply. Ensure that the copper electrode and nail do not touch each other.
- Allow the electric current to flow through the circuit for about 5 minutes.
- Remove the nail.

Discussion

1. Describe the appearance of the nail.
2. Does the plating metal wear off?
3. Where do you think that the substance coating the nail came from?

14.8.2 Don't change it — cover it up

One way of overcoming the shortcomings of a metal is to cover it with a thin layer or 'plate' of another metal. This can be done by electroplating the metal. The process of electroplating is described in *Investigation 14.4*. Metals like silver, gold, nickel, chromium, zinc and tin can be plated onto iron objects to improve their appearance, reduce cost or protect them from corrosion. For example, the chromium plating on bicycle handlebars improves their appearance and reduces corrosion. Silver-plating knives, spoons and forks makes them look like silver even though they are made of a cheaper metal. Electroplating provides the shiny coating on teapots, car parts and many other items.

14.8.3 Taking advantage of the properties

By mixing metals with other metals and with non-metals to form **alloys**, their properties can be changed to make them more suitable for particular purposes. For example, although iron is quite hard and strong, it corrodes quickly and is dull. On its own it is not strong enough to support the loads required of structures like bridges and buildings, cranes and railway lines. Iron is combined with varying quantities of other elements to form steel.

Carbon steel is an alloy of iron with differing amounts of carbon. The presence of carbon makes the steel stronger than iron, its base metal. The steel used to make hammers and similar tools contains more carbon than the steel used to construct the steel panels used to make cars. By including tungsten in steel, its melting point is increased. Stainless steel is an alloy of iron, chromium and nickel. The added metals increase its resistance to corrosion and make it more shiny.

Some alloys of copper and iron

Alloy	Main components	Properties and uses
Cupronickel	Copper and nickel	Resistant to corrosion; durable; used for silver-coloured coins ($1 and $2 coins contain more copper and some aluminium as well as nickel)
Bronze	Copper and tin	Resistant to corrosion; durable; harder than copper and tin; gold in colour; used in statues and ornaments
Brass	Copper and zinc	Resistant to corrosion; malleable; durable; harder than copper and zinc; gold in colour; used in ornaments and decorative fittings
Stainless steel	Iron, nickel and chromium	Resistant to corrosion; malleable; shiny when polished; used in eating utensils, kitchen sinks and medical instruments
Cast iron	Iron, carbon and silicon	Harder and stronger than iron; not malleable but is shaped when molten by pouring into a mould; used to make car engine blocks, machinery, fire hydrants and some building materials
Carbon steel	Iron and carbon	Harder and stronger than iron; used in buildings, bridges, car and bicycle frames and kitchen appliances
Tungsten steel	Iron, carbon and tungsten	Hard, strong and resistant to high temperatures; used in tips of high-speed drills and mining drills

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. **Recall** four properties of metals that make them useful materials.
2. **Define** the term 'alloy'.
3. **Recall** three possible benefits of electroplating.

Think

4. **Explain** why alloys are more commonly used than pure metals.
5. **Explain** why tungsten steel is more heat resistant than carbon steel.
6. Most of the alloys in the table above include small amounts of elements other than those listed. **Explain** why these small amounts may be present.
7. **Account** for the fact that electroplating a metal object can make it cheaper.

Imagine

8. Imagine a world without metals! **Construct** a list of items that could no longer be manufactured if a mysterious force from outer space suddenly destroyed all metals in the Earth's crust. Where possible, suggest materials that could be used to replace the metals used in these items.

Investigate

9. **Investigate** the main components, properties and uses of each of the following alloys: solder, nichrome, amalgam, alnico, Wood's metal, duralumin, carboloy and pewter. Organise your findings in the form of a table similar to the one shown above.
10. **Identify** which property of metal makes it suitable for certain uses by completing the **'Time Out' Metals** interactivity.

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Complete this digital doc: Worksheet 14.6: The uses of metals (doc-12477)

Try out these interactivity: 'Time Out' Metals (int-0757)

14.9 Avoid, re-use or recycle

14.9.1 What is rubbish?

Almost half of the waste that Australians throw out as household rubbish consists of packaging and food containers made from plastic, glass, metal and paper (or cardboard). These materials are all made or extracted from the Earth's natural resources. Food and plant waste are biodegradable. They can be broken down in the soil by microbes and other decomposers such as worms. Even paper and cardboard break down fairly quickly. However, plastic, glass and metal are not biodegradable. If they are thrown out with other household rubbish such as food and garden waste, they are buried in landfill tips like the one pictured at right. They take hundreds or even thousands of years to break down. This creates the need for more rubbish tips. Of course, there is a limit to how much land can be used for rubbish tips in and around major towns and cities.

Dumping rubbish in a landfill tip is not just unsightly and smelly. It is not sustainable. Poisonous chemicals in the rubbish can leak into the soil and end up in rivers and streams, endangering living things.



14.9.2 Think about packaging

At least three questions should be asked before you buy a packaged product:

- Is the product available without packaging or with less packaging?
- Is the package recyclable?
- Is the package re-usable or biodegradable?

If the packaging is plastic, glass, aluminium or steel, it is probably recyclable, saving non-renewable resources, energy and even water.

It's in the bag

Plastic supermarket bags are not recyclable and they interfere with the automatic sorting machines in recycling plants. In 2009 Australians disposed of more than 20 000 tonnes of plastic bags in landfills. To make matters worse, many discarded plastic bags end up in creeks, rivers and the sea. Marine animals such as whales and seals can swallow them and choke or get tangled in them, eventually dying of starvation. Turtles and some sea birds mistake them for jellyfish and eat them, causing them to choke or be unable to digest food. There is a simple way to avoid these problems. Don't use them! Use reusable bags instead.

14.9.3 Looking after your PET

There are two very good reasons for recycling plastics:

- Plastics are non-biodegradable. That is, they are not broken down naturally by micro-organisms. Plastics add thousands of tonnes of new rubbish to the environment every year.
- Plastics are made from oil — a resource that is expensive and dwindling. The continued production of new plastic is not **sustainable**.

Household waste contains many different types of plastic, which need to be separated. The plastics industry has introduced a code system to help consumers identify recyclable plastics. The symbols shown below make the sorting of plastics before recycling easier and cheaper. Some plastics are more easily recycled than others because of differences in the structure of the chains of molecules of which they are made.



PETE

PET or PETE (polyethylene terephthalate) is used to make plastic soft-drink bottles. Most commonly known as PET, this plastic is recycled to make carpet fibre and flower tubes. Empty PET bottles completely and remove the lids before placing them in a home recycling bin. The lids are recyclable, but their small size makes the sorting process awkward.



HDPE

HDPE (high-density polyethylene) is used to make plastic milk and fruit juice bottles. This plastic is recycled to make bottles, crates, pipes, 'wheelie' bins and playground equipment. Empty HDPE bottles completely and remove the lids before placing them in a home recycling bin.



V

Polyvinyl chloride, more commonly known as PVC, is used to make pipes, fencing and bottles containing substances other than food. It is not easily recycled and can be dangerous to your health and the environment. PVC bottles can be placed in your home recycling bin as long as the lids are removed. They are separated from the more easily recyclable plastics and sent to a separate plant for processing.



LDPE

LPDE (low-density polyethylene) is used to make wash bottles and other containers. These are recyclable and can be placed in your recycling bin. LPDE is also used to make supermarket plastic bags, which should not be placed in your home recycling bin. These bags interfere with the automatic sorting machines in recycling plants. It is best to avoid them by using reusable shopping bags instead.



PP

PP (polypropylene) is used in synthetic fibres to make clothing, industrial fibres, car batteries, bumper bars and other car parts. Although these products are not appropriate for your recycling bin, polypropylene can be recycled for use in carpet, furniture, white goods and even polymer bank notes. Most car workshops, scrap metal dealers and service stations will accept used car batteries for recycling.



PS

Polystyrene is a very light plastic used in solid form to make plastic cutlery, toys and cases for CDs and DVDs. In its softer foam form, it is used for disposable drinking cups and packing materials. Polystyrene products should not be placed in home recycling bins. The lightness of polystyrene foam makes it difficult to sort and recycle. Although all polystyrene can be recycled, it is a very expensive process.



OTHER

Other plastics, including nylon, fibreglass and polycarbonate, are not generally recycled and should not be placed in your home recycling bin.

See-through recycling

About 45 per cent of the glass packaging used in Australia is recycled. Used glass bottles, known as **cullet**, are collected and melted down in a furnace to produce new products. The overall energy saving is only 8 per cent of that used in making new glass. This is because of the high cost of collecting and melting down the bottles. In some countries, milk is sold in bottles that can be sterilised and reused up to 50 times before they need melting down, which saves a large amount of energy.

INVESTIGATION 14.5

Design your own waste disposal system

AIM: To investigate waste management

Your group is responsible for preparing a report on ways to improve the household waste management and disposal for the shire of Green Valley.

The shire currently collects rubbish from its 134 500 ratepayers using large green bins that are emptied by compactor trucks. The rubbish is taken to the local tip and used as landfill, at a cost to the council of $60 per tonne. The tip is nearing capacity and will be closed within twelve months. Waste paper is collected separately by a private recycling company.

Discussion

Produce a report in written form or as an audio or a video file. Your report should address the following issues.

1. How will the shire encourage each household to produce less waste?
2. Is recycling too costly?
3. If recycling occurs, will recyclable wastes such as plastics, glass and metals be separated at a disposal station after collection, or collected in separate containers from households?
4. What measures will be used to encourage households to use compost bins?
5. How will the shire dispose of rubbish when the landfill site closes?

14.9.4 Saving trees

Over a million tonnes of paper, about a third of our annual consumption, is recycled in Australia. Paper is made out of fibres of the chemical cellulose and is relatively easy to recycle. Waste paper is first mixed with water to separate the fibres. Additives such as ink and adhesives are then removed, producing low-quality fibres that can be used to make cardboard and other products. Steam rollers are used to improve the quality of the finished paper.

Although the timber used to make paper is a renewable resource, we are using it more quickly than it regrows. If this continues, the habitats of many animals and other plants will slowly disappear, eventually resulting in extinction. Recycling paper reduces the amount of new paper needed, saving millions of trees.

This compost bin, made from recycled polypropylene (PP), is 220 L in capacity and is sold to various councils across Australia. The compost decreases in volume as it breaks down. Almost 50 per cent of domestic waste in Australia is material suitable for composting.



And metal too!

Metals such as steel and aluminium are easily recycled as long as they can be cheaply separated from other rubbish. Steel cans, aerosol containers, jar lids and bottletops can be recycled. The recycling of aluminium cans saves huge amounts of energy. Twenty aluminium cans can be recycled with the same amount of energy needed to produce just one new can.

Recycling aluminium cans. About 70 per cent of the aluminium cans used in Australia each year are recycled.



Sorting it out

The separation of the items in your recycling bin relies on differences in their physical properties including size, weight, magnetic properties and even colour. For example, items of different weights can be separated using blasts of air or a centrifuge that works like the spin dryer of a washing machine. Steel can be separated from other metals by a large magnet.

14.9.5 Special recycling programs

There are separate recycling programs for some products that cannot be placed in home recycling bins. These recycling programs are generally used to collect products containing substances that would endanger the environment or the community if they were dumped in landfill tips. For example, printer cartridges can be placed in recycling boxes at many Australia Post outlets and retail stores that sell computers and printers. Mobile phones can be left at most mobile phone outlets for recycling. Use the **Recycling** weblink in the Resources tab to find out where computers and other electronic equipment, white goods such as fridges and washing machines, corks, light globes and many other items are collected for recycling. This site also provides information about how to dispose of chemical wastes from home, school or industry. Oil, paints and unused medicines should not be placed in rubbish bins or flushed down the sink.

You can make a difference

The three bin collection system used by many city and shire councils throughout Australia makes it very easy for you to make a difference to the environment by recycling.

During the twelve months to June 2009, Hornsby Shire in NSW recycled 18 000 tonnes of paper. That's the equivalent of:

- saving over 299 000 gigajoules of energy. That's enough to power 13 870 homes for a year!
- preventing 9032 tonnes of greenhouse gas from entering the atmosphere. That's like taking 2169 vehicles off our roads — permanently!
- saving over 298 million litres of water. That's enough to fill 119 Olympic-sized swimming pools!

Imagine the combined effect of all cities and shires Australia wide!

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. How are biodegradable substances different from those that are not biodegradable?
2. What are the main benefits of recycling plastics?
3. Why are plastics such as PET now identified by a code?
4. What is cullet?
5. The first part of the process of recycling paper involves mixing it with water. What is the major purpose of mixing the paper with water?
6. List three problems associated with the disposal of waste in landfill sites.
7. Why is only a small amount of energy saved when glass is recycled?

Think

8. **Identify** at least two of the Earth's natural resources that are used to recycle each of the following.
   (a) Glass
   (b) Cardboard
9. **Identify** two of the Earth's natural resources that are conserved by recycling each of the following.
   (a) Plastics
   (b) Aluminium
10. Using timber for paper products more quickly than trees can be replaced threatens the habitats of animals and other plants. **Describe** two other problems caused by tree removal.
11. What factors influence the decision as to whether it is worth recycling a resource?
12. If a plastic bag manufacturer claimed that the bags it produced were biodegradable, what evidence would you need to be satisfied that the claim was correct?

Create

13. Draw a poster that could be used to encourage people to do one of the following.
    (a) Recycle all plastic products
    (b) Reduce their use of LDPE plastic bags

(c) Separate household rubbish into different bins for more efficient recycling
(d) Recycle paper used at school
(e) Recycle newspaper
(f) Recycle aluminium cans

14. Use the **Recycling** weblink in the Resources tab to find out how you can dispose of each of the following substances at a nearby location.
(a) Unwanted paint
(b) Used motor oil
(c) Unwanted and out-of-date medicines

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Explore more with this weblink: Recycling

14.10 Water world

14.10.1 The water cycle

Water is essential for life on Earth. It is therefore our most precious resource. There is certainly plenty of water on the planet. Two-thirds of the Earth's surface is covered with water, but almost all of it is salt water in the oceans. The rest exists as ice in the polar regions, rivers, lakes and glaciers.

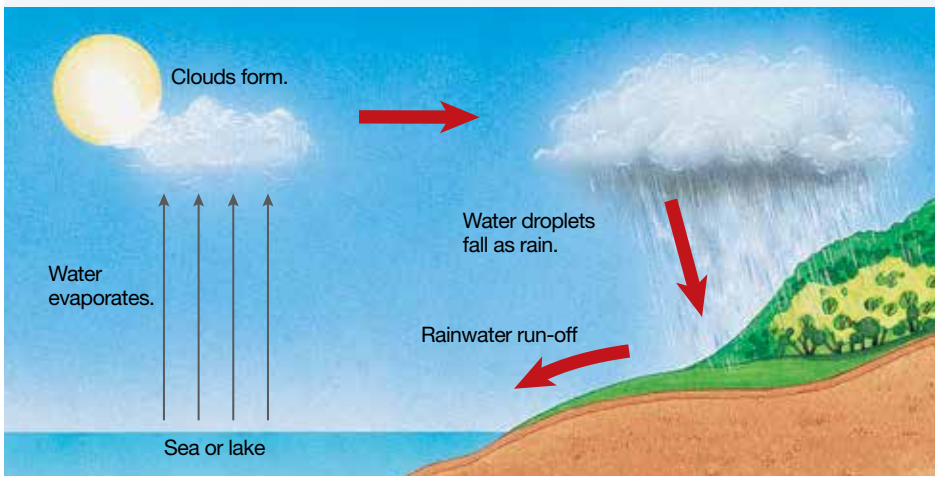
Water is constantly moving and changing states. It is in the oceans, in the icecaps and also in the air as water vapour. Heat from the sun makes water from the oceans evaporate slowly and form water vapour. The invisible water vapour rises with the warm air. When the water vapour becomes cold enough, it condenses to form **clouds** of tiny water droplets. The clouds are visible and are kept up by the air moving around them. If a cloud is close to the ground it is known as **fog**.



At high altitudes the air is very cold. When thick clouds reach this very cold area, the water droplets in them join together to form larger droplets, which are too heavy to be held up by moving air. The large droplets fall to the ground as rain.

Rainwater falls into the sea or runs over the ground into rivers and streams, eventually reaching the sea. This constant movement of water between the various states is called the **water cycle**.

The water cycle



INVESTIGATION 14.6

Water in the air

AIM: To demonstrate water vapour in the air

You will need:
very cold can of soft drink
towel

- Dry the outside of the can and allow it to stand on a bench or table.
- Observe what happens to the outside of the dry can.

Discussion

1. What change occurred on the outside of the can?
2. Where did the water come from?
3. What change of state has occurred?

INVESTIGATION 14.7

Forming clouds

AIM: To demonstrate how clouds are formed

You will need:
250 mL beaker
ice cubes
watchglass
heatproof mat, Bunsen burner and matches
tripod and gauze mat
safety glasses

Forming clouds in a beaker



- Half-fill the beaker with water and heat it until the water is boiling.
- Stop heating and cover the beaker carefully with a watchglass. Observe the bottom of the watchglass.
- Remove the watchglass and heat the water again until it boils.
- Stop heating and turn off the gas supply. Quickly but carefully, cover the beaker with a watchglass containing ice cubes.
- Observe the area under the watchglass.

Discussion

1. Describe what happened to the bottom of the watchglass when you first boiled the water.
2. Describe what happened in the beaker just below the watchglass containing ice cubes.
3. What changes of state took place?

14.10.2 Global warming

During daylight hours, heat from the sun enters the atmosphere and warms up the Earth's surface. At night, heat from the surface escapes through the atmosphere. Some of the gases in the atmosphere, including carbon dioxide, trap some of the heat. This trapping of heat is called the **greenhouse effect**.

Without a natural greenhouse effect, the Earth would be too cold to sustain life as we know it. Together, plants and animals help to keep the gases in the atmosphere in balance. During the day, plants take in carbon dioxide to help them make their own food. In doing so, they produce and release oxygen. Animals do the reverse, breathing in oxygen and breathing out carbon dioxide. For a very long time the amount of carbon dioxide and oxygen in the atmosphere has been fairly constant.

However, over the past 200 years the amount of carbon dioxide and some other heat-trapping gases has increased. As a result, the Earth's temperature is beginning to rise. The rising temperature is known as **global warming**. Two of the main reasons for global warming are:

- the burning of fossil fuels. Each year the world's population adds almost 30 billion tonnes of carbon dioxide to the atmosphere by burning fossil fuels — and the amount is growing year by year.

- the clearing of forests. Trees absorb carbon dioxide from the air and produce oxygen. As forests are cleared, this means of keeping the gases in the atmosphere in balance is removed. In Australia, two-thirds of all forests that existed 200 years ago have been cleared.

14.10.3 Global warming and the water cycle

The increase in the Earth's temperature is likely to have an impact on the water cycle and therefore the world's climate. There is already evidence that in Antarctica, where 70 per cent of the world's fresh water is stored as ice, the coastal ice shelf and glaciers are melting. The permanent cover of ice in the Arctic Circle is shrinking by an estimated 9 per cent every 10 years. As the polar icecaps shrink, rising sea levels could cause flooding of some islands and coastal cities. During the past 50 years, **hydrologists** have gathered evidence to suggest that climate change has already changed the water cycle and caused:

- less snow in high mountain regions
- more rain during wild storms and cyclones
- snow to melt earlier in the year.

Changes in the water cycle may also cause more heatwaves, droughts and bushfires.

Evidence that the water cycle is changing is gathered with technology such as:

- satellites and planes carrying sensors that collect information about clouds and surface moisture
- probes and other instruments to detect moisture in the Earth's crust and soil
- instruments that measure the flow of water on and below the surface
- radar to detect the presence and properties of clouds.

The massive amount of data collected by sensors and other instruments is used in computer simulations to improve our understanding of the water cycle, climate and weather. These computer simulations enable us to predict weather and future changes in the water cycle with more certainty and improve the sustainable management of water.

Cyclone Tracy, which devastated Darwin on Christmas Eve in 1974, killed 65 people (16 at sea) and injured 650. Nearly 70 per cent of homes were destroyed. Some 35 000 people had to be evacuated. Global warming could cause an increase in the number of cyclones like Cyclone Tracy.



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. **Explain** why water is described as our most precious resource.
2. **Recall** where most of the Earth's water is found.
3. **Recall** why sea water evaporates.
4. **Explain** what clouds are and how they form.
5. **Describe** the greenhouse effect and **explain** why it is important for life on Earth.
6. **Recall** two main reasons for global warming.
7. **Explain** how global warming is changing the water cycle.
8. **Explain** how evidence for changes to the water cycle is collected.

Think

9. **Explain** why some clouds pass over without producing rain.
10. **Identify** the changes of state that can be seen in the water cycle.
11. **Explain** why the water vapour in clouds condenses.
12. **Explain** why we can see clouds but not water vapour in the air.
13. **Discuss** how humans could alter the water cycle.
14. Is water a renewable or a non-renewable resource? **Explain** your answer.

Investigate

15. Use the library and the internet to **investigate** the importance of the Aboriginal rain dance.

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Watch this eLesson: The water cycle (eles-0062)

Complete this digital doc: Worksheet 14.7: Clouds (doc-12478)

Complete this digital doc: Worksheet 14.8: The water cycle (doc-12479)

14.11 Water management

Science as a human endeavour

14.11.1 Water use

Apart from Antarctica, Australia is the driest continent on Earth. Yet Australians are the third highest users of water per person in the world, surpassed only by the United States and Canada. In cities, households use 59 per cent of the available water. More than half of this is used for watering gardens and flushing toilets.

Until recently, people in major coastal cities had taken for granted the supply of clean water suitable for drinking. There was enough clean water available in dams to use for watering lawns and gardens, washing the car and filling swimming pools. However, in recent years, droughts have been responsible for severe water restrictions in most major cities and many smaller regional towns. According to a clear majority of scientists, climate change will result in an increase in the number and length of droughts.

Severe droughts have caused many dams to dry up.



All of this makes fresh water a natural resource that is far too valuable to waste. Its supply and use must be managed carefully and sustainably. It is up to every individual to recognise that good-quality fresh water is a precious resource that should be used wisely at home, in agriculture and in industry.

Dams and reservoirs

As Australia's population grows and climate change threatens to cause more and longer droughts, an obvious solution is to build more dams and reservoirs. However, building more dams and reservoirs is not always the best method of increasing water supplies. Dams on major rivers interfere with the flow of water downstream, causing problems for the environment and for farmers.

Myponga Dam, near Adelaide, South Australia. Building more dams like this is not always the best solution to improve water supplies.



14.11.2 Alternative water supplies

Presently, most of our water is collected in dams or pumped from aquifers deep in the ground (**ground water**). Neither source is sustainable. Alternatives are being examined, such as harvesting water from other sources, which would enable us to retain drinking water (**potable water**) for drinking only.

Rainwater: water captured from the roof in **rainwater** tanks. Many Australian states are now encouraging householders to install these tanks for toilet flushing or garden watering.

Grey water: water from the laundry and bathroom. Instead of going into a sewer, **greywater** is piped onto the garden. Water from the kitchen is generally too greasy to be used.

Stormwater: water that runs off surfaces into **stormwater** drains after heavy rain. It can be collected and treated in the same way as sewage.

Recycled water: water derived from **sewerage** systems or from industrial processes. Toilet waste is sometimes referred to as **blackwater**.

Drinking recycled water

In many countries around the world, treated effluent is discharged into rivers and streams that become sources of drinking water. Most water management authorities consider using recycled effluent for drinking water to be a last option, but in some places, such as Toowoomba, it may be inevitable.

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. (See *The tale of Toowoomba* below).

14.11.3 The tale of Toowoomba

Toowoomba, in Queensland, is a beautiful city renowned for its parks and flower gardens. Its Carnival of Flowers attracts thousands of visitors each year. In July 2006, the people of Toowoomba voted on a proposal for 25 per cent **recycled water** from the **sewage** treatment plant to be added to the city's rapidly diminishing water supply. Toowoomba's three dams had fallen collectively to below 20 per cent capacity.

The issue divided the city like no other issue ever had. In spite of a massive educational campaign, there was widespread fear among the voters and the proposal was defeated easily (61.8% : 38.2%).

In September 2006, level 5 water restrictions were placed on Toowoomba, which meant that the use of any tap water outdoors was prohibited. These were the toughest restrictions in Australia at the time.

HOW ABOUT THAT!

NASA engineers have collaborated with other scientists and engineers to develop a system that recycles water from air breathed out, sweat and urine into safe drinking water. It was first used by astronauts on the International Space Station. The system is now used in developing countries where water is scarce or heavily contaminated.

Volunteers in the northern Iraq village of Kendala help install and test a water purification system that has its origins in the space program.



14.11.4 Desalination — the answer to our water shortage?

Although fresh water is in short supply in Australia, the country is surrounded by sea water. Unfortunately, sea water is too salty to drink or water crops with; however, a desalination plant can remove the salt from sea water. Sydney's desalination plant at Kurnell, which commenced operation in 2010, is able to provide 15 per cent of Sydney's fresh water needs.

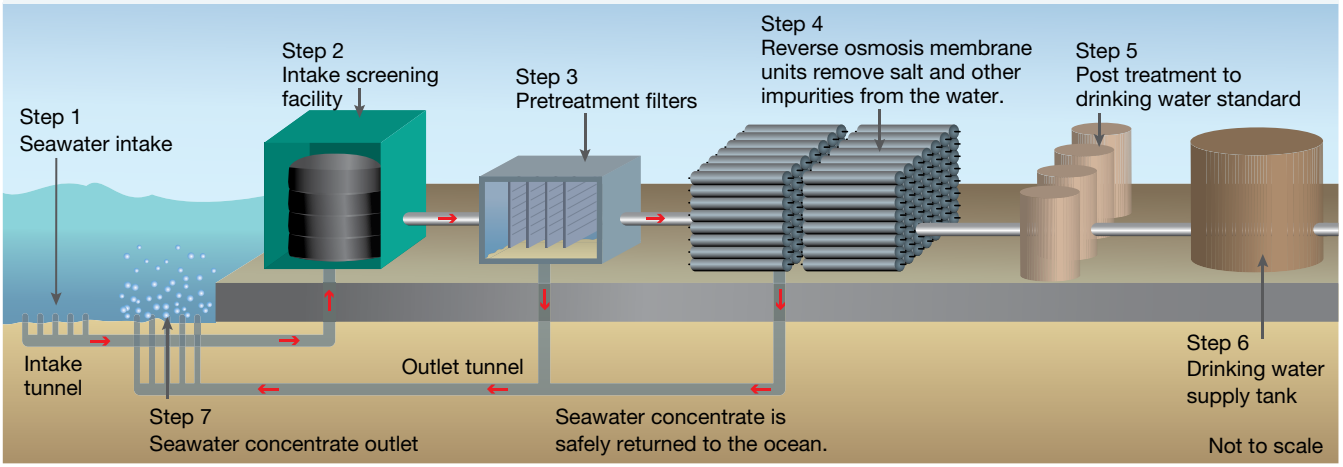
How does it work?

There are a few processes that can be used to remove salt from sea water. The Kurnell plant uses reverse osmosis. Reverse osmosis is the opposite of osmosis. In osmosis, water molecules from a solution with very little salt dissolved in it move from one side of a membrane into saltier water until the salt concentration is the same on both sides. This process occurs across the cell membranes of living things. 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.

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, the electricity needed to run it is provided to the NSW electricity grid by a wind farm at Bungandore near Canberra.

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

An example of a desalination plant



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 metres off shore. This may have a negative impact on sea life living very close to the salty water outlet.

14.11.5 Monitoring water quality

The first step towards maintaining the quality of our water systems and oceans is to monitor them. Various authorities carry out tests on rivers, streams and dams, and monitor the quality of the water. If unusual levels of pollution are found, attempts are made to identify the source of pollution and polluters may be fined.

Some schools participate in a program called Streamwatch. Participating schools are issued with a water testing kit and training, and agree to undertake regular testing of a water site close to the school. Each school submits its results online so that the data can be shared.

School students testing water quality



Lessons in sustainability

Over many thousands of years, indigenous Australians have successfully located and conserved fresh water in some of the driest parts of the continent. Some of their techniques for locating and conserving water provide valuable lessons for today's scientists and engineers as they meet the challenge of supplying a growing population with this precious resource in a sustainable way. Many indigenous techniques for locating and collecting water are used in survival training by the Australian Defence Forces.

INVESTIGATION 14.8

Monitoring water quality

AIM: To investigate some aspects of water quality

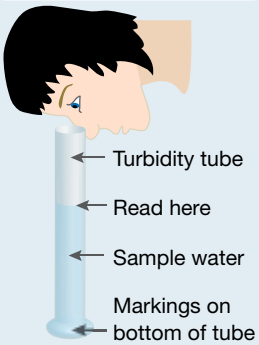
You will need:

samples of water from various locations
turbidity tube
data logger with the following probes: pH, temperature, dissolved oxygen, conductivity (Note: If your school does not have data loggers or you do not have some of the probes listed you could use a thermometer, pH meter and conductivity meter instead.)

- Copy the table below into your notebook.

Measurement	Site X	Site Y	Site Z
pH			
Temperature (°C)			
Dissolved oxygen (ppm)			
Conductivity (Sm^{-1})			
Turbidity			

How to use a turbidity tube



- Use the data logger and probes to measure pH, temperature, dissolved oxygen and conductivity.
- Place the turbidity tube on the floor and look down the tube. You should be able to see a mark on the bottom of the tube.
- Fill the tube using one of the samples until the mark can no longer be seen through the water. Record the turbidity reading from the side of the tube (see diagram).
- Repeat the steps above using the other water samples collected.

Discussion

1. Turbid water is not clear. You cannot see through it very well. Explain how the turbidity test works.
2. What could cause a high turbidity reading?
3. Why is it important to monitor the amount of oxygen dissolved in water?
4. Explain how sewage pollution might affect the dissolved oxygen level of a body of water. (*Hint:* Sewage contains organic matter that can be broken down by bacteria. Bacteria carry out respiration.)
5. Gases, including oxygen, are less soluble in hot water than cold water. How might an increase in water temperature affect fish living in the water?
6. What impact would acid rain have on the pH of a stream?
7. When salts are dissolved in water, its conductivity increases. Would you expect sea water or fresh water to have a greater conductivity?
8. Did any of the samples you tested appear polluted? Justify your answer.

14.11 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. **Explain** why fresh water is such a precious resource in Australia.
2. **Recall** how Australian households use the majority of their fresh water.
3. **Explain** why building more dams and reservoirs is not always the best method of increasing the water supplies of large cities.
4. **Define** the following terms.
   (a) Potable water
   (b) Greywater
   (c) Stormwater
   (d) Blackwater
   (e) Desalination
5. **Explain** reverse osmosis.

Think

6. **Explain** why the majority of people of Toowoomba would have voted against using recycled water from a sewage treatment plant despite the desperately low water levels in the city's dams.
7. **Outline** at least two arguments that could have been used to persuade the people of Toowoomba to vote for the use of recycled sewage water.

8. Imagine that a new desalination plant has been proposed for your state in a yet-to-be decided location, using the same reverse osmosis technology as the Kurnell plant.
   (a) **Identify** and **describe** the factors that need to be considered before choosing a location.
   (b) **Identify** and **explain** the questions that need to be asked before a final decision is made to build the plant.

Design and create

9. List possible water-saving suggestions for your school. Design a poster or web page promoting these.

Investigate

10. In addition to the Kurnell plant, desalination plants have been constructed in Queensland, Victoria, South Australia and Western Australia. Research and report on:
    (a) the location of these plants
    (b) the process used to remove salt from sea water
    (c) how renewable energy is used to reduce the effects of desalination plants on the environment.
11. When European settlers set up crop farms in areas of Australia with low rainfall they set up irrigation systems to water their crops. The water for irrigation came from river systems and aquifers including the Great Artesian Basin. Use the internet, a library or your own resource to research and report on:
    (a) the size and location of the Great Artesian Basin
    (b) which river basin provides the source for most of the irrigation in New South Wales
    (c) the environmental impact of irrigation.
12. Use the **Water saver** weblink in the Resources tab and play the water saving game.
13. To find out more about saving water in your home use the **Investigator** weblink in the Resources tab and be a home water investigator.
14. To take part in the waterworks adventure, use the **Waterworks** weblink in the Resources tab.
15. Use the **Indigenous weather knowledge** weblink in the Resources tab to research and report on:
    (a) how Aboriginals and Torres Strait Islanders used the story of the Rainbow Serpent to predict changes in the water cycle from season to season and locate sources of water in the desert
    (b) what today's scientists can learn about the water cycle and water as a resource from the knowledge of indigenous people.

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Complete this digital doc: Worksheet 14.9: Testing water (doc-12480)
Explore more with this weblink: Water saver
Explore more with this weblink: Waterworks
Explore more with this weblink: Indigenous weather knowledge

14.12 Review

14.12.1 Study checklist

Earth's resources

- **distinguish** between renewable and non-renewable resources and give examples of each 14.2
- **describe** and **compare** the formation of coal, oil and natural gas 14.2
- **explain** how mineral deposits are accumulated 14.2
- **identify** minerals that are found in Australia 14.2
- **discuss** how indigenous Australians located and used the Earth's resources 14.11

Mining and using the Earth's resources

- **describe** the processes of open-cut mining and underground mining 14.3
- **outline** the process by which oil and natural gas are located and retrieved 14.3
- **describe** the use of coal, oil and natural gas as fuels 14.4

- **describe** the properties and uses of hydrocarbons found in crude oil **14.4**
- **recall** that most plastics and detergents are made from some of the hydrocarbons in crude oil **14.4**
- **explain** the difference between natural and synthetic fibres and **discuss** their advantages and disadvantages **14.4**
- **describe** the use of a range of renewable energy resources, giving examples **14.4**
- **explain** why alternative energies are being developed to reduce the dependence on fossil fuels **14.2, 14.5**
- **explain** how geologists detect ore bodies **14.6**
- **explain** how metals are removed from their mineral ores **14.6**
- **outline** the issues that must be considered before a decision is made to undertake mining after an ore body is discovered **14.7**
- **describe** the purpose of an environmental impact statement **14.7**
- **recall** at least four properties of metals that make them useful **14.8**
- **describe** how an alloy differs from a pure metal and **explain** why they are sometimes used instead of the pure metal **14.8**

Recycling

- **distinguish** between biodegradable and non-biodegradable materials **14.9**
- **evaluate** the suitability of different types of packaging for recycling or re-use **14.9**
- **outline** the requirements and development of systems for the recycling of household waste **14.9**

Water and its management

- **recognise** the importance of water as a natural resource **14.10**
- **describe** the water cycle in terms of the physical processes involved **14.10**
- **explain** the impact of global warming on the water cycle and weather patterns **14.10**
- **evaluate** some strategies for maintaining and conserving water supplies including recycling and desalination **14.11**

Individual pathways

ACTIVITY 14.1
Revising Earth's resources
doc-10581

ACTIVITY 14.2
Investigating Earth's resources
doc-10582

ACTIVITY 14.3
Investigating Earth's resources further
doc-10583

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FOCUS ACTIVITY

online only

Research how Aboriginal and Torres Strait Islander peoples used their knowledge to care for the land and water.

Access more details about focus activities for this chapter in the Resources tab (doc-10580).

14.12 Review 1: Looking back

assessON

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. Apart from the colour, **describe** the differences between brown coal and black coal.
2. **Explain** why you are more likely to find a fossil like the one shown below in a coal deposit rather than in a deposit of copper ore.



3. The diagram below represents an oil rig above a source of oil.



   (a) **Describe** a property of the rock found directly above a layer of oil that is different from the properties of the rock in which the oil is trapped.
   (b) **Identify** what is likely to be found in the cavity directly above the layer of oil.
4. Are the precious minerals obtained from mines renewable or non-renewable? **Explain** your answer.
5. What happens to most of Australia's black coal after it is mined?
6. Coal, oil and gas are all resources that exist below the surface of the Earth in large amounts.
   (a) **Explain** the difference between the way that coal is formed and the way that oil and gas are formed.
   (b) **Explain** the difference between the ways that coal and oil are obtained from below the Earth's surface.
7. Why is it so important for countries like Australia to reduce their dependence on fossil fuels such as coal, oil and gas?
8. The world presently consumes 6000 Mt of coal per year. According to one environmental agency, we will run out of coal in 400 years time if we keep on using it at this rate.
   (a) Given that 1 Mt equals one million tons, **calculate** how many tons of coal the environmental agency assumes still remains in the Earth's crust.
   (b) According to the World Coal Institute, listed in the table at right were the top seven coal-producing countries in 2007.
      (i) **Calculate** how much coal is produced in total, per year, by these seven countries.
      (ii) Do these seven countries provide, in total, enough coal for the world's needs? **Explain**.
      (iii) Using the information in the table, **construct** a bar graph.

Country	Coal produced/year (Mt)
China	2549
USA	981
India	452
Australia	323
South Africa	244
Russia	241
Indonesia	231

9. Use the table of hydrocarbons on page 553 to determine how many hydrogen atoms there are in one molecule of:
   (a) methane
   (b) ethane
   (c) octane
   (d) triacontane.
10. From which non-renewable resource are plastics and detergents made?
11. One factor that determines the way in which mineral ores are mined is their depth. **Compare** the mining processes used for mineral ores located near the Earth's surface with the mining processes used for mineral ores located deeper in the crust.

12. Copy and complete the table of mineral ores and metals. In the third column, list as many uses of each metal as you can think of. You might need to do some library or internet research to discover some of the uses.

Mineral ore	Metal	Uses of the metal
Haematite		
Bauxite		
Chalcopyrite		
Sphalerite		
Galena		

13. According to many geologists, parts of Antarctica are rich in mineral resources similar to those found in Australia. **Construct** a two-column table to list reasons why these mineral resources should be mined and reasons why they should not be mined.
14. Match the terms in the first column of the table below with the correct descriptions in the second column.

Term	Description
(a) Gangue	A A renewable fuel produced by the remains of living things
(b) Mineral	B A mixture of a metal with other metals or non-metals
(c) Hydrocarbons	C Easily moulded
(d) Ore bodies	D Unwanted substances that have to be separated from mineral ores
(e) Synthetic	E Regions with high mineral concentrations
(f) Alloy	F Manufactured; not natural
(g) Plastic	G Compounds made up of hydrogen and carbon atoms
(h) Biomass	H Chemical elements or compounds that are formed by geological processes

15. List two benefits of recycling:
    (a) plastic
    (b) aluminium.
16. Some plastic containers are marked with this symbol.
    (a) What substance would you expect to find in bottles made from this type of plastic?
    (b) What two things should you do before placing bottles made from this type of plastic in a recycling bin?
    (c) State two uses for this type of plastic after it has been recycled.



PETE

17. Create a circular flow chart to describe the water cycle.
18. **Explain** how clouds are formed and how they can develop into rain.
19. **Outline** the concerns that people have about desalination plants.
20. A PMI chart can be used to consider the positive (plus), negative (minus) and interesting aspects of an issue. Create your own personal PMI charts to display the positive, negative and interesting aspects of the following.
    (a) The use of nuclear energy to generate electricity in Australia
    (b) Wind farms
    (c) Permanent water restrictions to conserve water supplies
    (d) Building more dams and reservoirs to increase our water supply

Test yourself

1. Synthetic fibres such as nylon and polyester are derived from
   (A) cotton.
   (B) coal.
   (C) crude oil.
   (D) natural gas. **(1 mark)**
2. Which of the following is a renewable resource?
   (A) Aluminium
   (B) Brown coal
   (C) Polyester
   (D) Wood **(1 mark)**

3. Clouds are made up of
   (A) water vapour.
   (B) steam.
   (C) water droplets.
   (D) fog. **(1 mark)**
4. Which of the following can be used in the production of fresh water?
   (A) Salt water
   (B) Sewage
   (C) Urine
   (D) All of the above **(1 mark)**
5. Uranium has become a valuable resource since the introduction of nuclear power. Australia is one of the world's largest suppliers of uranium. It is mined in several places around the country, then exported overseas to nations that use it to generate electricity.

   The uranium industry is worth millions of dollars to the Australian economy and generates thousands of jobs. However, there are some negative aspects of mining uranium. These include: the environmental hazards of mining, the hazards associated with exposure to radioactive substances, the location of the uranium deposits and the way the end product is used. Strict guidelines are imposed on uranium mining companies. The aim of these regulations is to make the mining process and transport of the resource as safe as possible.

   Your task is to produce two brochures:

   (a) The first brochure presents arguments against uranium mining. This brochure should include environmental and social reasons to stop mining (and, therefore, using) uranium.
   (b) The second brochure explains the process of uranium mining and the measures taken to ensure safety. This brochure should also outline the positive aspects of mining and using uranium. **(6 marks)**

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Complete this digital doc: Worksheet 14.10: Resources from the Earth puzzles (doc-12481)

Complete this digital doc: Worksheet 14.11: Resources from the Earth summary (doc-12482)

TOPIC 15
Ecology

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?

Rainforests are not just pleasant places to visit; they are significant from an ecological perspective. Ecology is the study of the interactions between living things and their environment and between different species of living things. Rainforests are important because they contain many species of living things that are not found anywhere else. If we do not look after our forests, some of these species may become extinct.

Another important role of forests is to produce oxygen and remove carbon dioxide from the atmosphere. Animals, including humans, need the oxygen that plants produce to survive. Is it any wonder that people are so passionate about forests?

LEARNING SEQUENCE

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Forests are important for the health of our planet.



What is ecology?

1. Define the terms ‘ecology’ and ‘photosynthesis’.
2. What would happen if all forests throughout the world were destroyed?
3. (a) Four ecosystems are shown in the photos on this page. In what way are they different? Include information about temperature variations, availability of light and availability of water.
   (b) Give examples of the types of living things you might find in each of the ecosystems.
   (c) The rainforest plants would not survive in the desert. Similarly, the desert plants would not survive in the rainforest. Explain why.
4. Create a table with the following column headings: ‘Term’, ‘Dictionary definition’, ‘Definition in my own words’. Write the words listed below in the first column. Use a dictionary to complete the second column. As you come across each word in this topic, write down a definition of the term in your own words in the third column.
   ecosystem, habitat, distribution, abundance, collaboration, symbiosis, mutualism, parasitism, commensalism, epiphyte, saprophyte, extinct, endangered, consumer, producer, decomposer, adaptation, respiration, photosynthesis
5. Use the **Test tube with David Suzuki** weblink in the Resources tab, in which he explains the concept of exponential growth. Explain how this relates to ecology.
6. Use the **Human footprint** weblink in the Resources tab to investigate how your lifestyle impacts on our planet. Outline some things you could do to reduce your ecological footprint.









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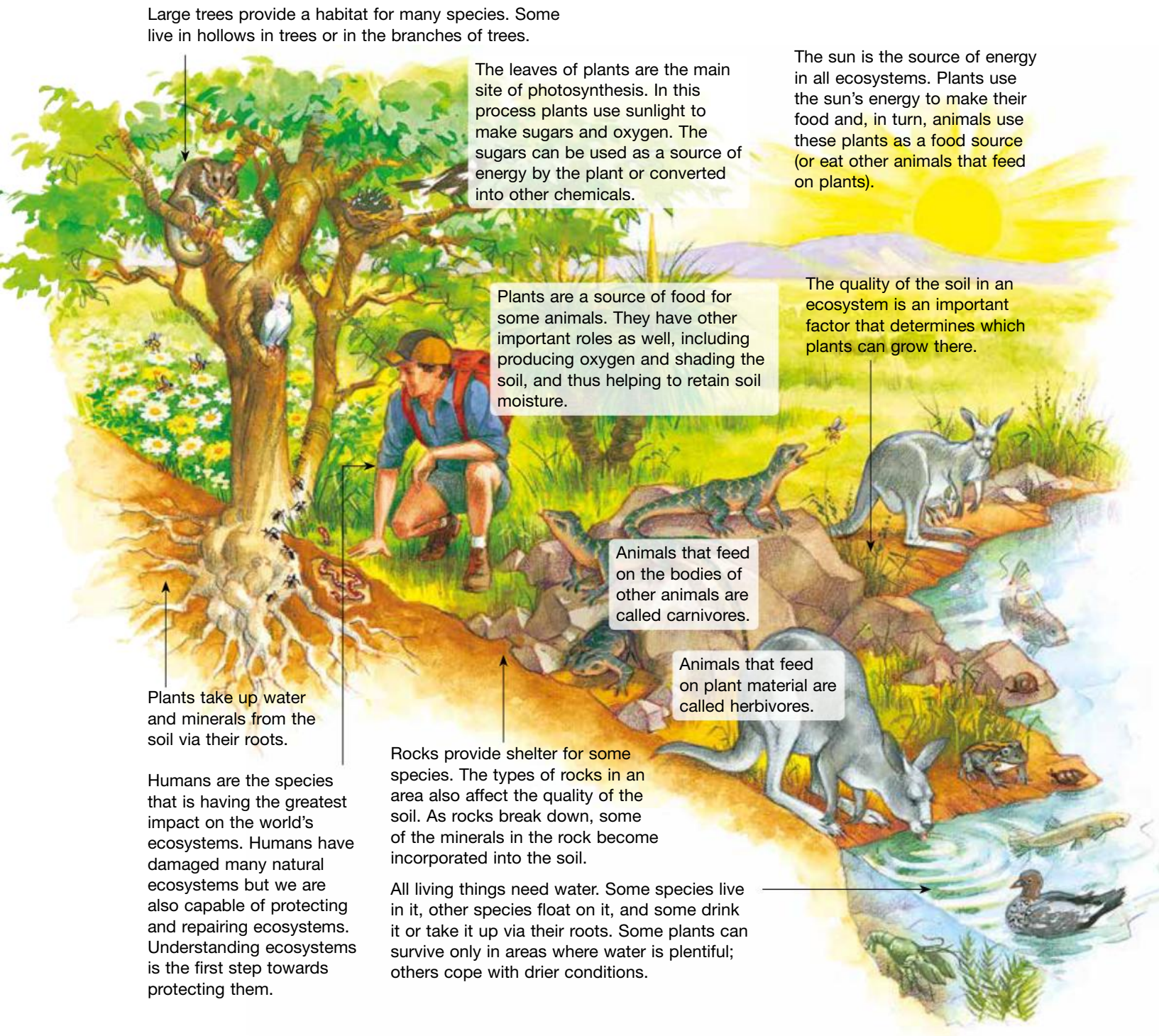
Explore more with this weblink: Test tube with David Suzuki

Explore more with this weblink: Human footprint

15.2 A place to call home

15.2.1 Ecology

Next time you go for a walk in bushland or along a rock platform, take a good look around. Try to count the different types of living things that surround you. Some organisms such as trees and large animals are very obvious, but there are many smaller creatures and plants that are easier to miss. There are also microscopic animals living in the soil. The living things in natural environments, regardless of their size, depend on each other and on their surroundings for survival. **Ecology** is the study of the way in which organisms interact with other organisms and with their environment.



15.2.2 It's all about relationships

The habitat for these starfish is a rockpool.



An **ecosystem** is made up of living and non-living things that interact with each other. A pond, a rock platform and a rainforest are all examples of ecosystems. The living things in an ecosystem (the **organisms**) are referred to as the **biotic factors**. The non-living features are called the abiotic factors. Abiotic factors include temperature, soil type, rainfall patterns and amount of light available. The abiotic factors determine the types of organisms that can survive in an area and, in turn, the living things affect the abiotic features of an ecosystem. The living things also interact with each other.

A **habitat** is the place where a particular organism lives. For example, the habitat of the platypus is the freshwater creeks, rivers and lakes of eastern Australia. A living thing's habitat provides the things it needs to stay alive. The habitat for the starfish shown in the photo at right is a rock pool. It provides the starfish with a source of food, water, oxygen and shelter.

Sydney funnel-web spider



The **distribution** of a species tells us where it is found, whereas the **abundance** or **density** of the species tells us how many of these organisms live in a particular area. For example, the Sydney funnel-web spider (*Atrax robustus*) is found in New South Wales, from Newcastle to Nowra and west to Lithgow. That is its distribution. In Sydney, there are more funnel-web spiders in the northern suburbs than in the southern suburbs, so we can say that the abundance or density of funnel-web spiders is higher in the northern suburbs of Sydney than in the southern suburbs of Sydney.

Determining the distribution and abundance of endangered species is very important. Endangered species are at risk of becoming extinct. If we know where a particular species lives, it may be possible to protect its habitat. For example, while the Olympic site was being planned in Sydney, some green and golden bell frogs were found in the historic Brickpit. Although this was the proposed location for the tennis courts, the architects went back to the drawing board. The courts were relocated and additional ponds suitable for the frogs were created. The abundance of these frogs at Olympic Park has been monitored by the Australian Museum and appears to have remained steady despite the building of the Olympic site.

HOW ABOUT THAT!

Professor Marsh studies dugongs. Dugongs are mammals that live in the ocean and feed on seagrass. Her research initially involved studying the carcasses of dugongs that had died in shark nets. She worked out a way of estimating the ages of dugongs by studying their tusks. Later she focused on the reproductive cycle of dugongs. Professor Marsh has also been involved with studies using aerial pictures to estimate the abundance of dugongs in various areas. By measuring the abundance of dugongs regularly, it has been possible to identify areas where dugong numbers are falling and suggest strategies to maintain dugong numbers.

Helene Marsh bottle feeding a dugong



INVESTIGATION 15.1

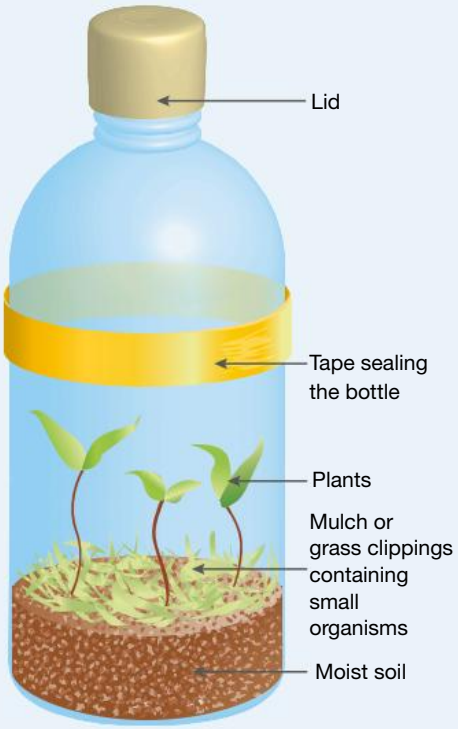
A mini ecosystem

AIM: To create your own ecosystem

You will need:

1 L clear plastic bottle
scissors or knife
masking tape
soil or potting mix
small plants or seedlings
grass clippings or ground mulch (including small organisms). If there are few organisms in the grass clippings or mulch, you may want to add ants or slaters.

- Cut the top off the bottle.
- Pour the soil or potting mix into the bottom of the bottle.
- Plant the seedlings into the potting mix.
- Place the ground mulch or grass clippings over the potting mix and around the seedlings.
- Add sufficient water to moisten the soil.
- Put the top back on the bottle and seal it with masking tape. The bottle should be completely sealed so that no air, nutrients, animals or plants can be added or removed from the mini ecosystem for the duration of the experiment.
- Observe your mini ecosystem each lesson for the duration of this topic.



Discussion

1. Explain why it is not necessary to regularly water the plants in this ecosystem.
2. The living things in the ecosystem use up oxygen.
   (a) Recall what the living things need oxygen for.
   (b) Why doesn't the oxygen run out?
3. Where do the living things get their energy from? Why is there no need to feed them?
4. If the ecosystem is balanced, the organisms inside the bottle continue to live for a very long time without needing extra water or food.
   (a) Explain what a balanced ecosystem is.
   (b) What could cause this mini ecosystem to become unbalanced?

INVESTIGATION 15.2

Why are most producers green?

AIM: To investigate the pigments in leaves

In this investigation, you will extract coloured chemicals called pigments from plant leaves. The pigments found in leaves include chlorophyll, a substance that is involved in photosynthesis and is green in colour. The pigments will be separated using a technique called **chromatography**.

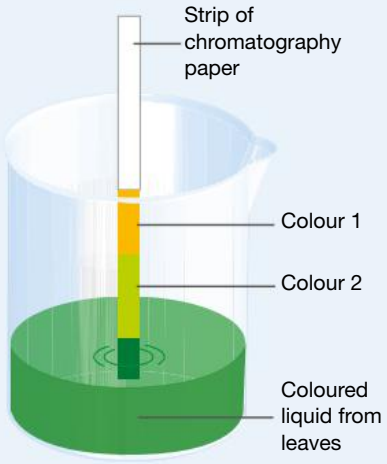
You will need:

large beaker
hotplate
leaves from seedlings or plants: geranium, hydrangea, lettuce, spinach or silverbeet cuttings are excellent
metal tongs
large test tube or small beaker
methylated spirits
test-tube holder
stirring rod
clear plastic wrap
medium-sized beaker
filter or chromatography paper

CAUTION: Methylated spirits is toxic and extremely flammable.

- Half-fill the large beaker with water and bring to a gentle boil on the hotplate. This large beaker will serve as a water bath.
- Soften two or three leaves by dipping them with tongs into the hot water for 10 seconds.
- Place the leaves into a test tube or small beaker and cover them with 30–40 mL of methylated spirits. Use a test-tube holder to hold the test tube or small beaker upright in the water bath, so that its contents do not spill into the water.
- When the leaves turn pale and the methylated spirits deepens in colour, remove the test tube or small beaker from the water bath.
- Decant the coloured methylated spirits into the medium-sized beaker. Allow the liquid to cool for 10 minutes.
- Suspend a long narrow strip of chromatography paper or filter paper in the beaker so that just 2–5 mm sits in the liquid as shown in the diagram at right. Fold the paper over the side of the beaker to hold it in place.
- Remove the strip of paper from the methylated spirits before the colours reach the top of the paper.

Chromatography separates colours in mixtures.



Discussion

1. Record the colours that you have found in the liquid.
2. How many different colours could you identify?
3. What seems to be the most prominent colour?

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Explore more with this weblink: Rockpool
Complete this digital doc: Worksheet 15.1: Ecosystems and habitats (doc-12483)
Complete this digital doc: Worksheet 15.2: Biotic and abiotic factors (doc-12484)

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. Match each term with its meaning.

Term	Meaning
Organism	Living component of an ecosystem
Abiotic factor	An aquatic mammal that feeds on seagrass
Biotic factor	Living thing
Herbivore	The range over which a species is found
Habitat	Animal that feeds on other animals
Dugong	An indication of the number of organisms of a particular species in an area
Abundance	Animal that feeds on plants
Carnivore	The place where a particular organism lives
Distribution	Non-living features of an ecosystem

2. Rocks, water and soil are non-living, but they are important to the survival of living things. Use the information on page 589 to **outline** why.

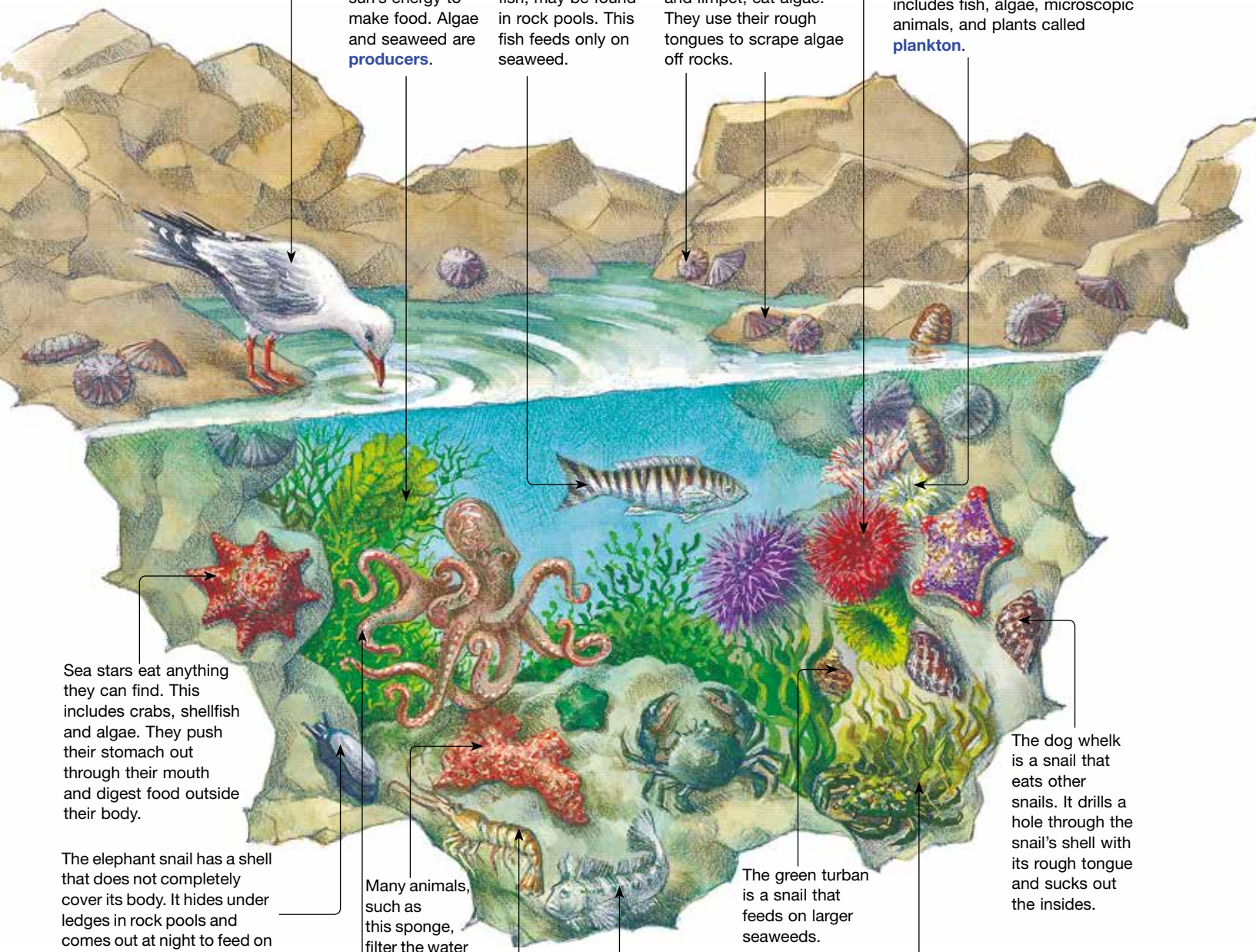
Think

3. Study the picture on page 589. If the tree was chopped down, which animals would be affected? In what way?
4. Imagine that the water in the creek became badly polluted. How would this impact on the living things in this ecosystem? Which would be affected first?
5. (a) **Explain** why organisms living in a rock pool need to be able to cope with significant fluctuations in temperature and salinity (salt level).
   (b) **Describe** other factors that organisms in rock pools have to withstand.
6. Use the **Rockpool** weblinks in the Resources tab to create a PowerPoint presentation on the organisms found on rock platforms on the coast of NSW. Include photos and descriptions of the organisms and information about the adaptations that allow these organisms to survive on the rock platform.

15.3 Who's hungry?

15.3.1 What can you see in a rockpool?

Food chains are a useful way to show the flow of energy in ecosystems. Plants grow using energy from the sun. Some animals eat plants; others feed on animals that may themselves have fed on plants. Ultimately, the sun is the source of all the energy in ecosystems.



15.3.2 What do they eat?

Plants do not eat food; they can make their own sugars and other energy-rich substances in a process called photosynthesis. When plants carry out photosynthesis, they use the sun's energy to convert carbon dioxide and water into sugars and oxygen. Plants are the producers in ecosystems.

Animals need to eat food; they are **consumers**. Animals that feed only on plants are called **herbivores**. They are also called first-order consumers. Animals that feed only on other animals are called **carnivores**. **Omnivores** feed on both animals and plants. Humans are omnivores. In an ecosystem, the second-order consumers are the animals that eat the first-order consumers, and the animals that eat the second-order consumers are called third-order consumers.

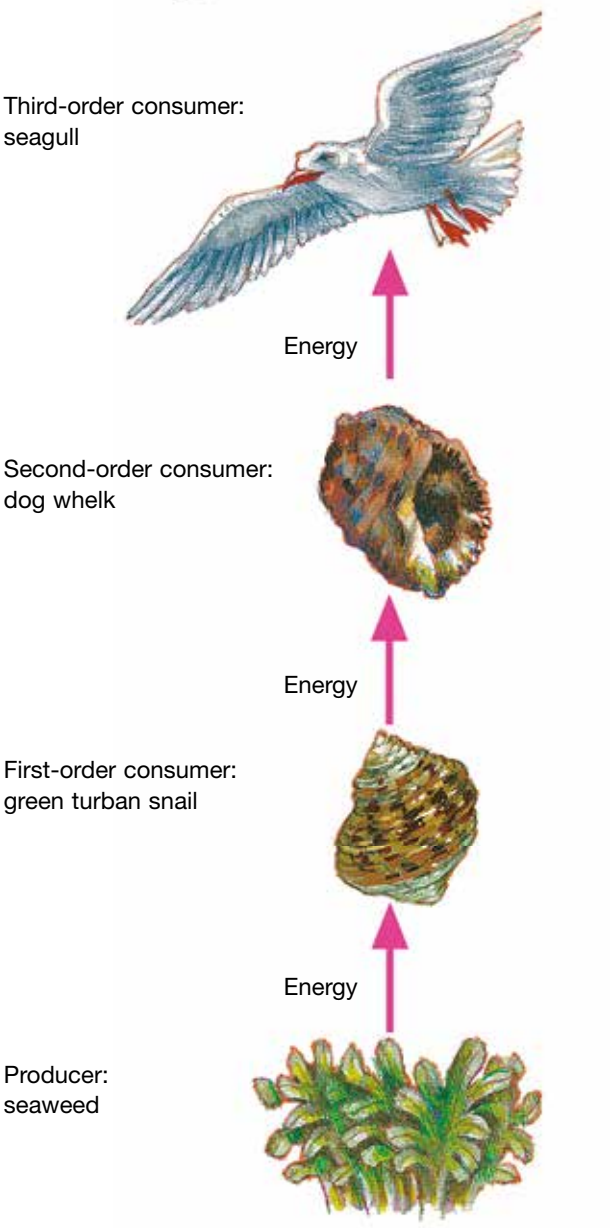
Hunting or hunted?

An animal that hunts another animal is called a **predator**. The animal it hunts is called its **prey**. An example of predator–prey relationship in the diagram at right is the relationship between the seagull and the dog whelk. The seagull is the predator and the dog whelk is the prey.

Food chains

A food chain shows the direction in which energy flows in an ecosystem. Food chains always start with a producer. At right is one of the food chains for the rock pool on page 593. The seaweed is the producer. When the green turban snail feeds on the seaweed some of the energy locked up inside the seaweed is passed on to the snail. Some of this energy is then passed onto the dog whelk, which eats the snail, and, in turn, a portion of the energy is passed on to the seagull.

A food chain showing the direction of energy flow



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. **Define** the terms 'producer', 'consumer', 'herbivore', 'carnivore', 'omnivore', 'predator' and 'prey'.
2. **Explain** the statement: 'Ultimately, the sun is the source of all the energy in ecosystems.'
3. Complete the word equation for photosynthesis: carbon dioxide + _____ → sugars + _____.
4. **Distinguish** between first and second-order consumers.
5. Give an example of a prey–predator relationship.
6. What do the arrows in a food chain show?

Skill builder

7. Copy the table below in your book and add the name of each organism labelled on page 594 to the appropriate column.

Producers	Herbivores	Carnivores	Omnivores

8. **Construct** three food chains using information from the diagram on page 594.
9. Find an example of each of the following in the diagram on page 595.
   (a) First-order consumer
   (b) Second-order consumer
   (c) Third-order consumer
10. Use the information below to construct three food chains.
    - Crickets eat grasses.
    - Echidnas feed on ants and termites.
    - Frill-necked lizards eat insects (including crickets, ants and termites) as well as mice.
    - Kookaburras feed on small reptiles (including lizards), small birds and mammals such as mice.
    - Termites eat dead trees, grass and leaves.
    - Mice eat seeds.

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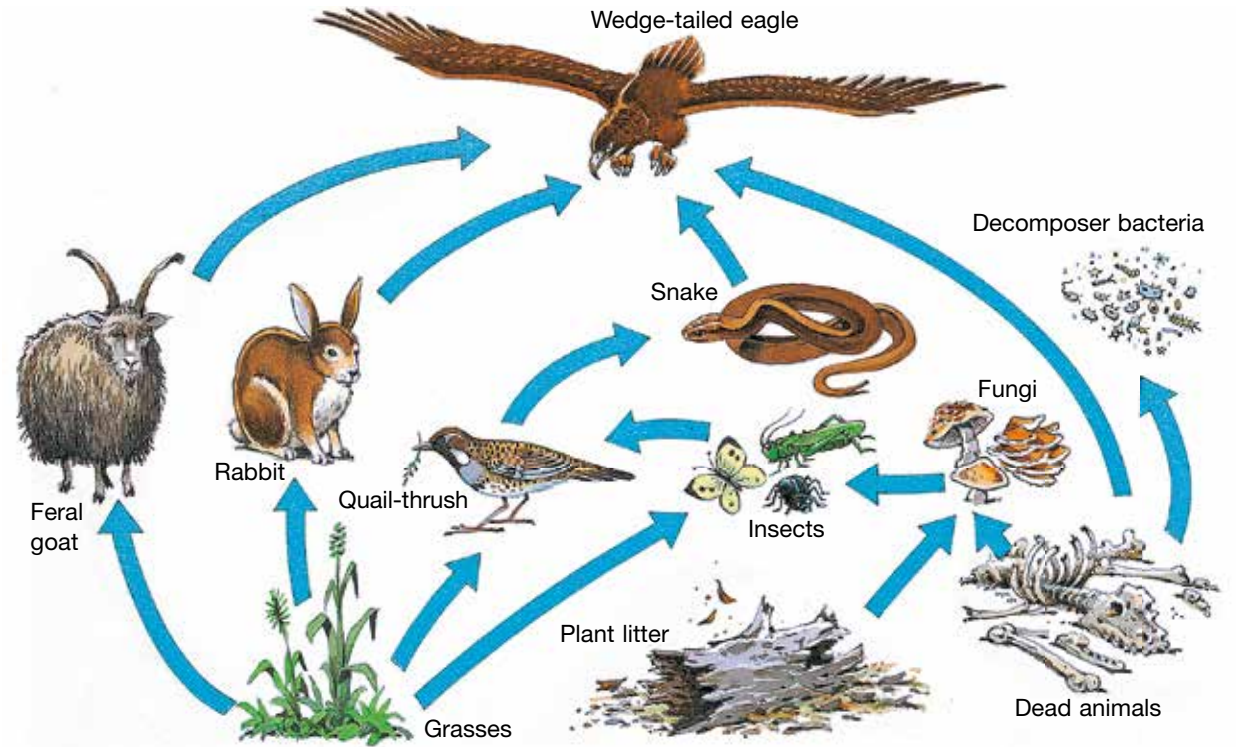
Complete this digital doc: Worksheet 15.3: Food chains and food webs (doc-12485)

15.4 Caught in a web

15.4.1 Energy pyramids

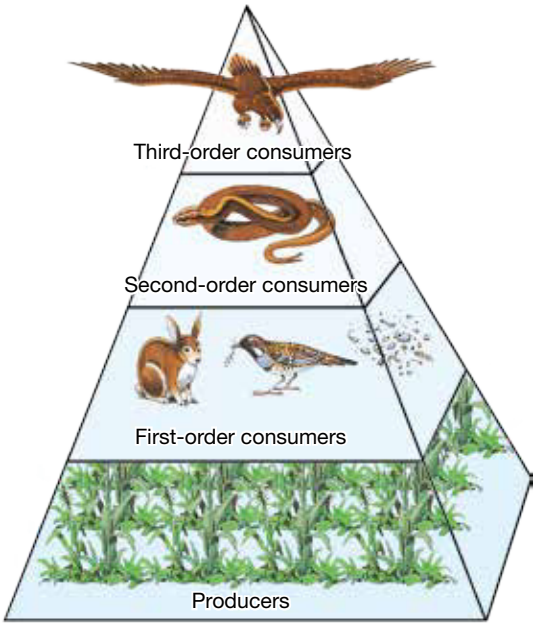
Food chains tell only part of the story when describing the flow of energy in ecosystems. Most living things eat a variety of things. A food web shows how different food chains connect together.

A food web showing the flow of chemical energy through different organisms in an ecosystem



When constructing a food web, the producers are usually placed at the bottom. The producers are the lowest trophic level in a food web. The first-order consumers are the second trophic level and the second-order consumers are the third trophic level. As energy flows through ecosystems, only a portion of the energy is transferred from one level of the food web to the next. What happens to the remainder? It is converted to other forms of energy, mainly heat. Since only a very small proportion of the energy locked up in the producers makes its way to the top of a food web, an ecosystem requires a large number of producers to support a small number of top-order consumers.

This food web has four trophic levels.



15.4.2 Biomass pyramids

Another way to think about the trophic levels in an ecosystem is in terms of biomass. The biomass of a trophic level is the dry mass of the organisms that make up that level. In a balanced ecosystem, the amount of biomass decreases with each trophic level. A huge mass of plant matter is needed to support a significantly smaller mass of herbivores, and an even smaller mass of second- and third-order consumers. The top-level producers make up only a very small part of the biomass in the ecosystem.

HOW ABOUT THAT!

When a great white shark attack makes the headlines, invariably there are calls for sharks to be hunted down and for better measures to protect swimmers from sharks. Are sharks just misunderstood creatures that need to be protected rather than exterminated? Scientist Barry Bruce is attempting to find the answer to this and other shark-related questions.

The great white shark is the top-order consumer in its ecosystem, so a decrease in their numbers could lead to overpopulation of the species they prey on. This, in turn, would impact on species lower down the food chain. Barry Bruce has been tracking great whites to find out their preferred habitats, investigate their travel patterns and find out which shark populations interact.

The work is tricky. The sharks need to be captured and held in a specially designed cradle so that an electronic tag can be fitted. Once the tag is in place, it can monitor the shark's movements until the tag's battery runs flat. The data gathered so far has provided useful information. For example, it has shown that sharks tend to stay in one area for some time; then, probably when their food supply dwindles, they move rapidly to another area and stay there for some time.

Use the **Shark tracking** weblink in the Resources tab to see the shark's tracks.

Barry Bruce and a colleague measuring a great white shark



INVESTIGATION 15.3

Field work

AIM: To study the components of an ecosystem

This investigation is best carried out in a natural ecosystem. Depending on the location of your school this could be a rock platform, a rainforest, bushland or an area near a creek.

You will need:

thermometer or temperature probe and data logger
wet–dry thermometer
wind vane
universal indicator
barium sulphate powder

Your school may also have other instruments available to collect information about the abiotic features of the environment (e.g. dissolved oxygen and salinity probes, turbidity tube, lux meter).

- Begin by collecting information about the abiotic factors of the environment.
  - Use the thermometer or temperature probe to measure the air and water temperatures.
  - Measure humidity with the wet–dry thermometer and wind speed with the wind vane.
  - Collect a sample of soil. If it is dry, add water until it has a consistency like thick paste. Sprinkle some barium sulphate powder over the soil, and then add a few drops of universal indicator. Compare the colour produced with the colour chart supplied with the indicator to determine the pH of the soil.
  - Use any other available instruments to collect additional information about the abiotic features of the environment.
- Use a digital camera or mobile phone to take photos of the different types of living things in the environment. Make note of where in the ecosystem you found each organism.

Discussion

1. Copy and complete the table below:

Abiotic factor	How measured	Units	Measurement

2. Write a description of the environment you studied.
3. Use reference material to identify the name of each living thing you found and use the photos you took to construct at least two food chains for the environment you studied.
4. Choose two of the organisms you photographed and outline some of their adaptations (features that help an organism survive in its environment).

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. **Distinguish** between a food chain and a food web.
2. **Identify** the organisms that are usually placed at the bottom of a food web.
3. Only a small portion of the energy stored in the organisms that make up the bottom trophic level of a food web is transferred to the next level. What happens to the energy that is not transferred?
4. **Outline** why researcher Barry Bruce has fitted great white sharks with electronic tags.

Skill builder

5. Write down three food chains for the food web on page 596.
6. Identify the following in the food web on page 596.
   (a) Producers
   (b) First-order consumers
   (c) Second-order consumers
   (d) Third-order consumers
7. **Identify** an omnivore in the food web.
8. Many grasses die during extended droughts. How would this impact on the number of wombats, kangaroos and dingos in the ecosystem?
9. How would a decrease in the echidna population impact on the dingo and termite populations?
10. The great white shark is a top-order consumer. **Explain** why it can be difficult to predict the impact of a reduction in the number of top-order consumers on producers and first-order consumers.
11. Refer to the information below to answer the questions that follow.
    - Snails eat water plants and algae.
    - Tadpoles eat algae.
    - Small fish eat snails, algae and water plants.
    - Large fish eat snails, small fish and tadpoles.
    - Humans eat small fish and large fish.

    (a) **Construct** a food web using this information. The producers should be at the bottom.
    (b) **Identify** which organisms:
    (i) are producers
    (ii) are first-order consumers
    (iii) are second-order consumers only
    (iv) are second and third-order consumers
    (v) are herbivores
    (vi) are omnivores
    (vii) compete for food
    (viii) have more than one food source.
    (c) **Predict** what would happen if overfishing led to a depletion in the number of large fish.
12. Use the **Food web** weblink and the information in the diagram on page 593 to create a food web for a rockpool ecosystem.

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Explore more with this weblink: Shark tracking

Explore more with this weblink: Food web

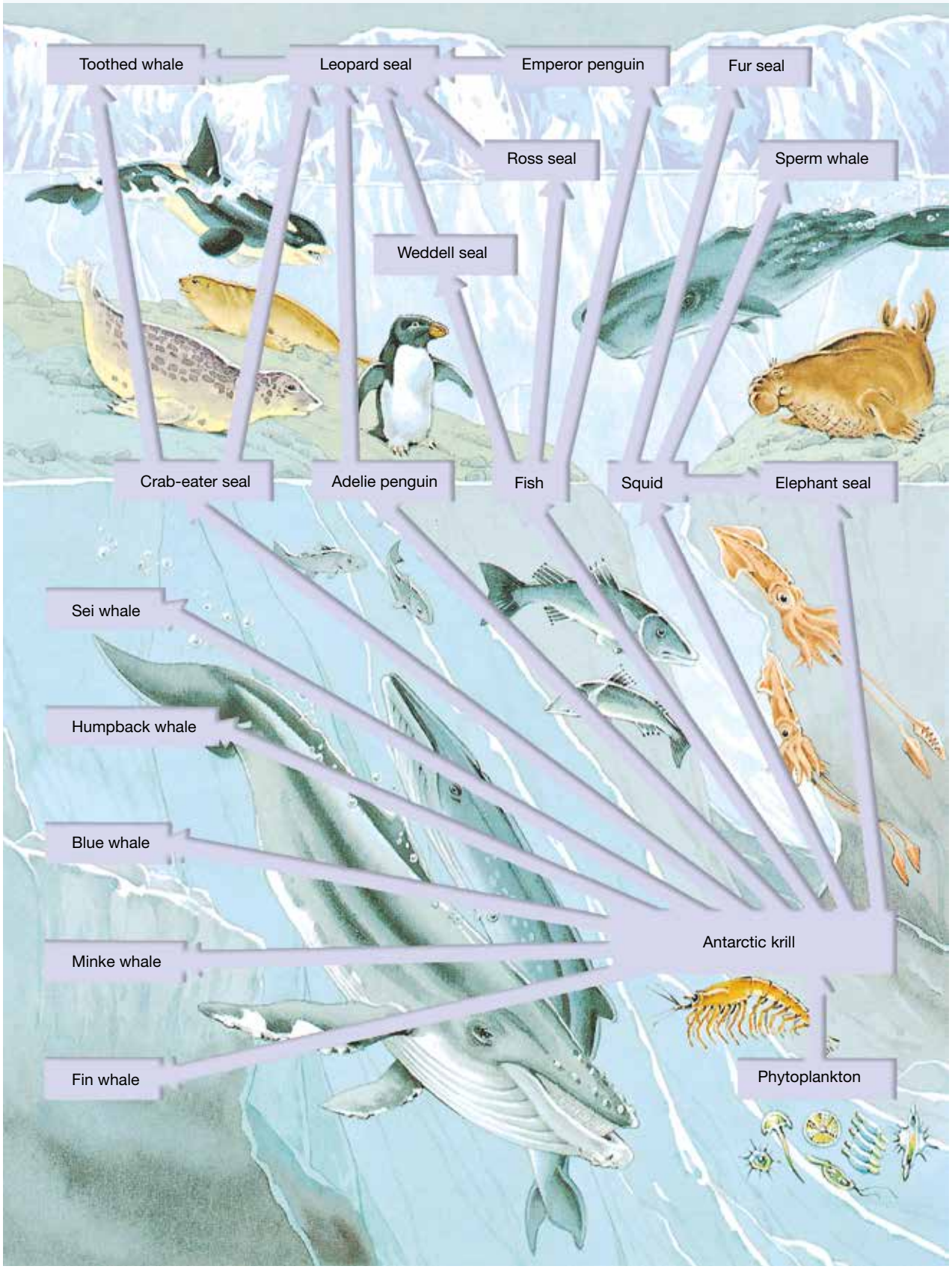
15.5 Antarctica — the last frontier

15.5.1 Secrets in the ice

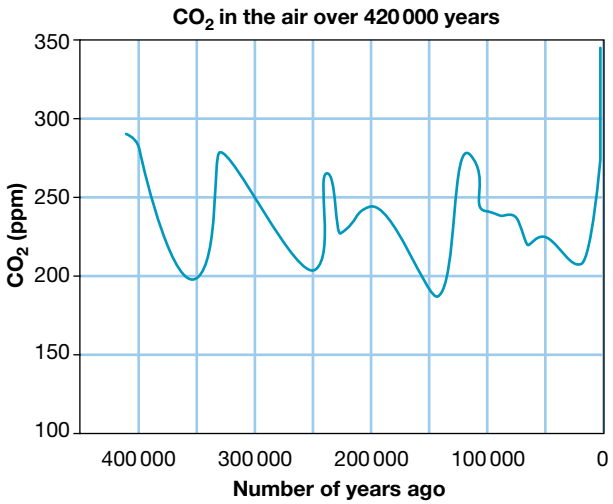
Antarctica is a very special place on Earth. Is it the coldest and driest continent and it is home to unique species. There are no permanent human residents in Antarctica but thousands of scientists from numerous countries visit Antarctica to work in the research stations scattered across the continent.

One important piece of research that has been carried out in Antarctica is the study of ice cores. The layer of ice over Antarctica has built up over time from the snow that has fallen over the continent. The ice near the surface formed from snow that fell recently, but the ice that is many kilometres below the surface formed from snow that fell over Antarctica hundreds of thousand years ago. Trapped in the ice are particles of dust as well as gases that were in the atmosphere at the time the snow fell. Scientists have drilled deep into the ice and analysed the ice samples. The data have enabled them to track how temperature and carbon dioxide levels have changed over the last 420 000 years. This is shown in the graphs on page 601.

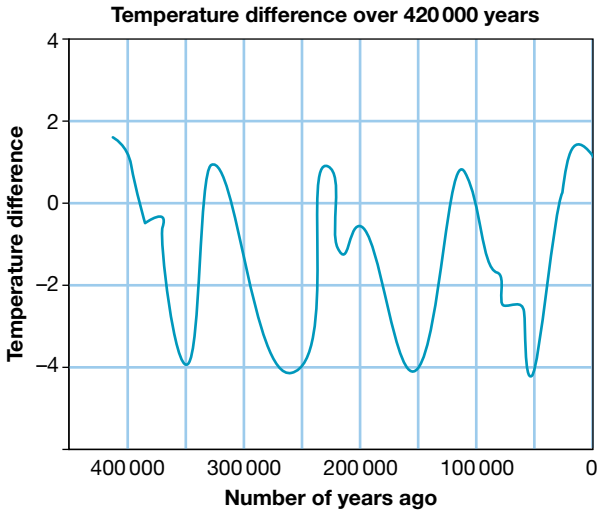
Food web in an Antarctic ecosystem



The ice core samples show that, during periods of warmer weather, there were higher levels of carbon dioxide in the atmosphere. During periods of cooler weather, carbon dioxide levels were lower. The data from the ice core samples are important. Human activity, including the burning of fossil fuels, has resulted in a rapid increase in carbon dioxide levels, which is contributing to global warming. Knowledge of past carbon dioxide levels and climate is useful in attempting to model the impact of rising atmospheric carbon dioxide concentration.

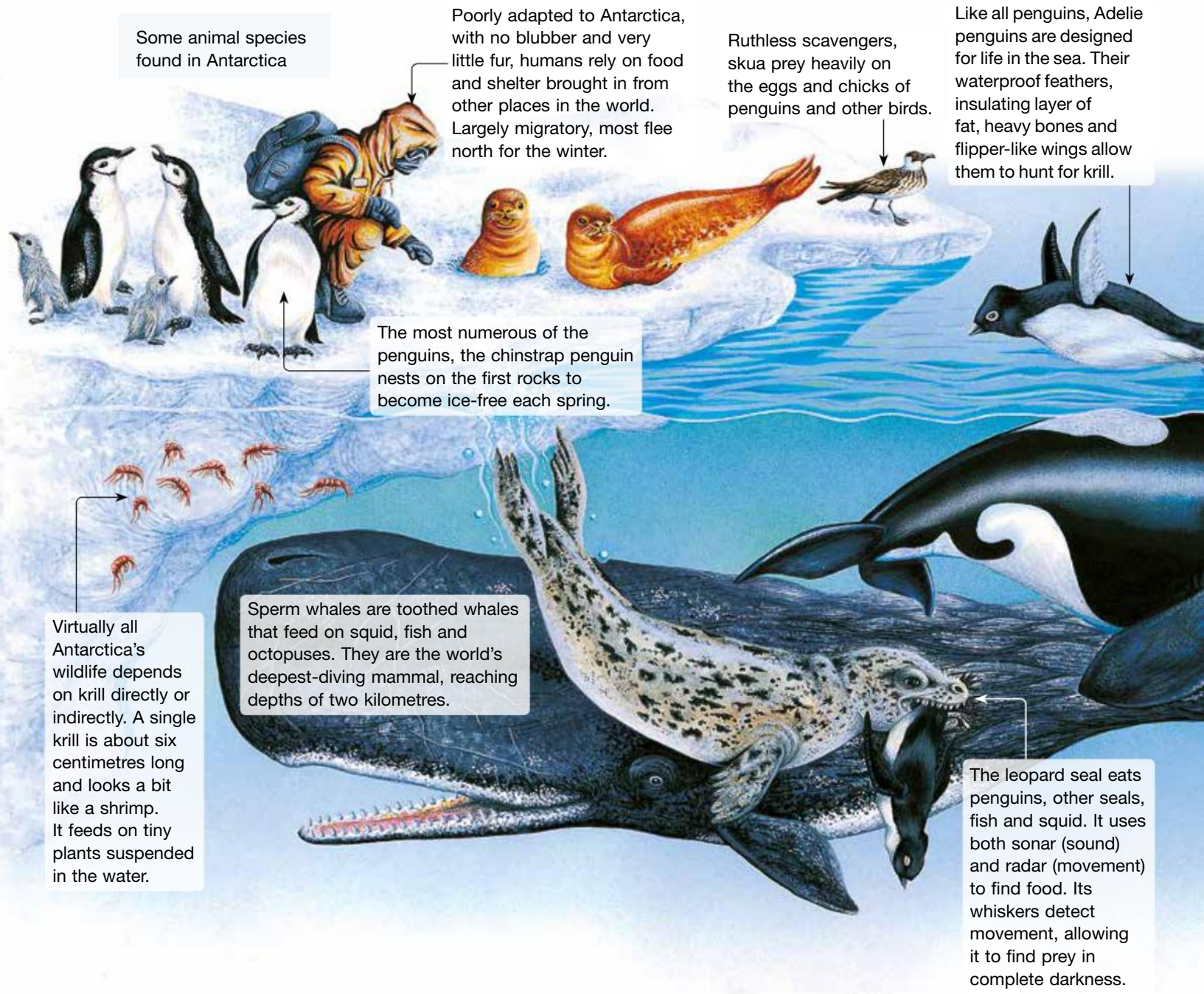


Over the last 420 000 years, the Earth has fluctuated between periods of cooler weather (ice age) and periods of warmer weather.



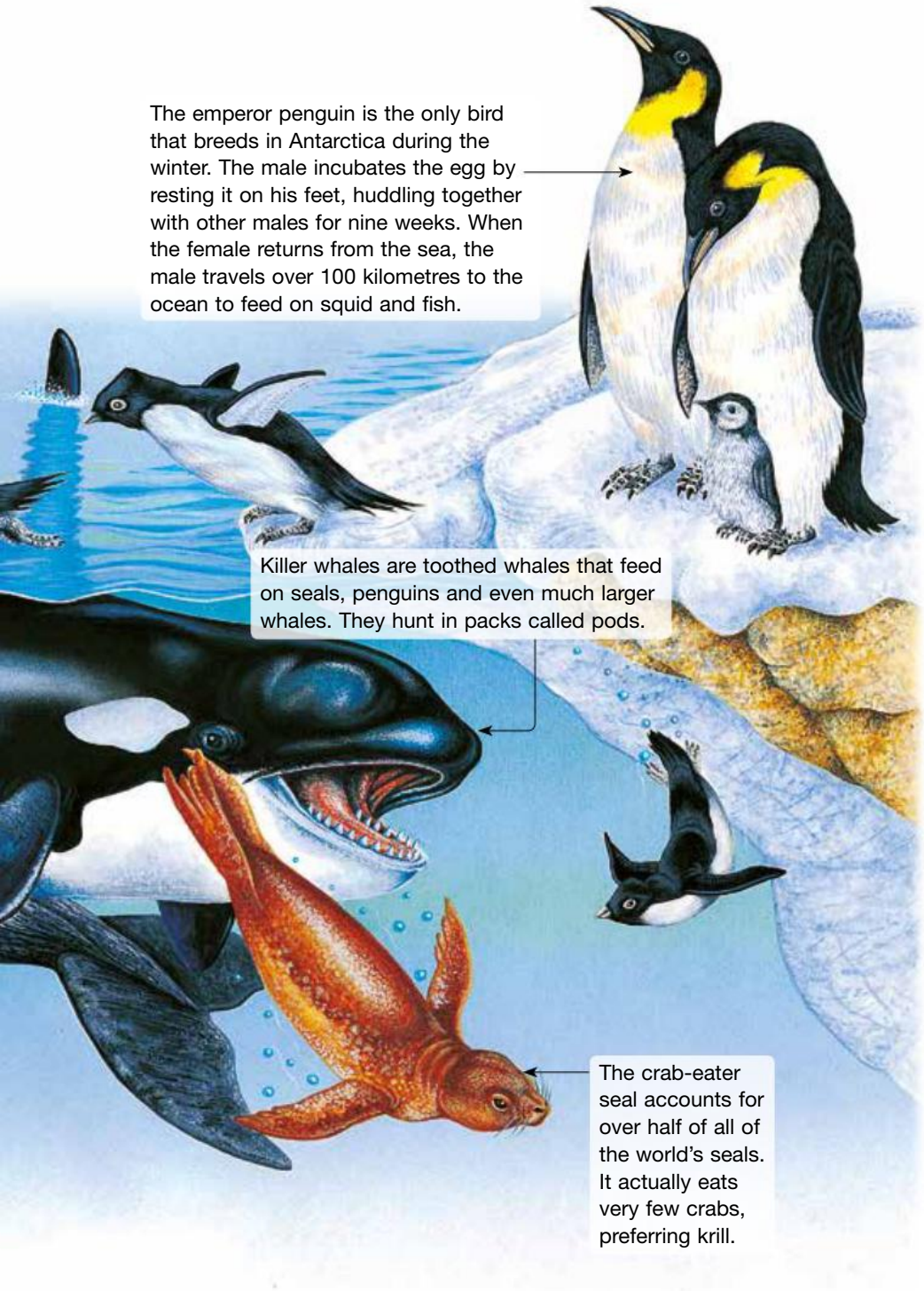
This ice core was drilled from more than 3.7 km down. Parts of it are more than 150 000 years old.





15.5.2 Scientists working together

In the late 1950s, 12 nations, including Australia, carried out scientific research together in Antarctica. This successful cooperation led to the 12 nations signing the Antarctica Treaty, a document in which the countries agreed to look after Antarctica and restrict its use to peaceful endeavours such as scientific research. Since then additional countries have signed the treaty. There are now close to 50 research stations



in Antarctica including four Australian stations. Scientists working on different stations often cooperate on projects.

The Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) was formed in 2003 to carry out research that focuses on Antarctic marine ecosystems, climate change, carbon dioxide and the ocean, and sea level rises. It involves Australian scientists, including CSIRO researchers, working with scientists from 13 other countries.

An important part of the work carried out by ACE CRC is to track changes in the size of the ice sheet over Antarctica. A huge amount of water is locked up in the ice sheet. Melting of the polar ice sheets due to rising temperatures is the most significant factor contributing to rising sea levels. Determining how quickly the Antarctic ice sheet is melting will help researchers model the impact of climate change on sea levels. One thing that has already been discovered is that the ice is not melting just on the surface. Large icebergs are breaking off and drifting away as well. This makes it even more challenging to work out just how quickly the ice sheet is shrinking.

The ACE CRC puts seals to work for climate change research!

Getting good data about ocean currents under thick layers of ice can be quite tricky, so Dr Steve Rintoul who is involved with the ACE CRC has enlisted the help of elephant seals. The seals have been fitted with sensors. The seals dive under the ice, so the sensors have provided data about areas of the ocean for which no other data were available.

So far, scientists have worked out that the Southern Ocean near the South Pole has warmed up faster than the average for the other oceans. This is very concerning. It means that the southern icecap might actually be melting faster than has been predicted. Models based on the average rise in seawater temperatures may have underestimated the speed at which the icecap is melting.

An elephant seal with an oceanographic sensor



HOW ABOUT THAT!

Scientists working at the Australian Antarctic Division have been studying the impact of whale poop on the ecology of the Southern Ocean. They are testing the hypothesis that the excrement of whales is rich in iron and acts as a fertiliser for the oceans, helping phytoplankton to grow. The tiny organisms in phytoplankton are the main producers in the Southern Ocean. The scientists suspect that a decrease in whale numbers has resulted in less whale poop being released into the ocean and, in turn, lower numbers of phytoplankton and thus less food for consumer organisms.

Scientists need to measure iron levels in the whale excrement, but the first step is to get hold of it. This involves going to areas where whales are feeding and waiting for the inevitable. Fortunately for the scientists, it's quite hard to miss when a whale is having a bowel movement. As much as half a tonne of waste can be produced! So, when a whale has done its business, the scientists get to work with scoops and collect some samples to test.

It's a dirty job, but someone has to do it!

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. What is the Antarctica Treaty?
2. **Identify** what the letters ACE CRC stand for.
3. **Outline** why scientists are collecting whale poop.

Think

4. **Explain** why ice cores can be used to get information about past conditions in Antarctica.
5. **Outline** the benefits of scientists collaborating on research.
6. Study the two graphs on page 601.
   (a) When was the most recent ice age?
   (b) What has happened to carbon dioxide levels over recent times?
   (c) Do carbon dioxide concentration in the atmosphere and temperature appear to be linked? **Justify** your answer.
7. **Explain** why a decrease in whale numbers has resulted in fewer phytoplankton growing and, in turn, less food for consumer organisms.

Skill builder

8. Study the diagram on page 600.
   (a) **Identify** a producer shown in the diagram.
   (b) **Construct** three food chains for the ecosystem shown.
   (c) **Identify** two predator–prey relationships.
   (d) **Identify** a first-order consumer.
   (e) **Identify** a second-order consumer.
   (f) Which organisms are the top-order consumers?
   (g) What would be the impact of a sudden decrease on the krill population?
9. The data below have been adapted from PR & AH Ehrlich, *Population, Resources, Environment* (W.H. Freeman, San Francisco, 1972).

	Number of whales killed					
Year	**1930**	**1940**	**1950**	**1960**	**1965**	**1970**
Blue whales	25 000	15 000	7 000	3 000	2 000	0
Fin whales	14 000	14 000	23 000	32 000	20 000	5 000
Sei whales	1 000	1 000	3 000	8 000	25 000	15 000
Sperm whales	1 000	5 000	12 000	20 000	30 000	23 000
Total						

   (a) **Calculate** the total number of whales killed in 1930 and 1970 only. **Compare** the two values. (Access the video instructions for this question by clicking on the **Whale spreadsheet** weblink in your Resources tab.)
   (b) **Construct** a line graph showing time on the horizontal axis and the total number of blue whales killed on the vertical axis.
   (c) **Describe** the trend shown in the graph drawn in part (b).
   (d) Produce a graph that shows the changes over time in the number of each type of whale killed and the total number of whales killed. Use the **Excel** weblink in your Resources tab to see how to do this using Excel.
   (e) Use the graph you produced to answer the following questions.
      (i) Which whale was killed less and less frequently over the whole period? Suggest a reason why.
      (ii) When was the total number of whales killed greatest?
      (iii) **Compare** the 1965 data with the 1970 data. What do you notice? Suggest a reason for this change.

Research

10. Whale watching is a popular tourist attraction in many coastal regions of Australia.
    (a) Use the **Whale watching** weblink in the Resources tab to find out what time of the year whales are most likely to be observed along the coast of NSW. Why are they in these waters at that time of the year?
    (b) Use the **Whaling history** weblink in the Resources tab to find out more about whaling in Australia. Produce a poster or use the **Glogster** weblink in your Resources tab to produce a glog.

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Complete this digital doc: Worksheet 15.4: Global warming (doc-12486)
Explore more with this weblink: Whale watching
Explore more with this weblink: Whaling history
Explore more with this weblink: Glogster

15.6 Friendly microbes

15.6.1 The bad guys

Microscopic organisms such as bacteria and some fungi can make you seriously ill, make your teeth rot and cause food to decay. Not all micro-organisms are bad news though. Some microbes are used to make food, and others play an important role in keeping us healthy. Microbes are also involved in the recycling of nutrients in ecosystems.

Bacteria and other micro-organisms are responsible for many diseases. Some diseases caused by bacteria include tetanus, pneumonia, meningococcal meningitis, tooth decay and some cases of sore throat and ear infections. Bacteria in food and water can cause food poisoning and gastroenteritis. Even pimples are caused by bacteria.

Bacteria can also cause disease in other animals and in plants. Anthrax and mastitis are bacterial diseases of cattle. Leaf blight and spot, found in plants, are bacterial diseases.

The rash on this patient's legs is caused by the bacteria responsible for meningococcal meningitis.



Micro-organisms are responsible for the decay of food. The microbes break down the food as they feed on the nutrients in the food. Storing food in the fridge slows down its decay as the low temperature slows down the growth of bacteria. Another way to keep food from rotting is to dry or freeze it. If there is little water available, or the water is frozen, bacteria cannot reproduce and the food will not decay. Microbes in food can also be killed by high temperatures or radiation. Canned food and long-life milk have a long shelf life because the microbes in these foods have been killed by heat.

Bacteria and fungi are responsible for the decay of food.



15.6.2 The good guys

Microbes are involved in the preparation of a range of foods. Yeast (a fungus) is used to make bread, and most alcoholic drinks including wine and beer. Many dairy products, including yoghurt, cheese, butter and sour cream, are made using bacteria. The tough outer coat of coffee and cocoa beans is broken down by microbes as part of the process involved in making coffee and chocolate. Without the action of bacteria,

olives would be inedible, pickles would be plain cucumbers and sauerkraut would simply be cabbage.

Some yoghurts contain live bacteria.



The human body is teeming with microbes. In the same way that organisms in ecosystems interact with each other and their environment, the various types of microbes living on and in the human body interrelate, sometimes competing and sometimes cooperating, and often impacting on our health and wellbeing. The bacteria that grow on the skin produce acid and make our skin slightly acidic. This inhibits the growth of harmful bacteria. Our intestines are home to numerous species of bacteria. Some help to break down the food we eat. Others produce important vitamins. The bacteria in our gut may also impact on the immune system — the system that fights disease. The type of food you eat and certain medications, including antibiotics, can affect the mix of bacteria that live in the digestive tract. This, in turn, can affect your health. For this reason, some people try to regularly eat food that contains 'good' bacteria. These foods include yoghurt that contains live cultures, some drinks and many food supplements.

Bacteria and fungi are also important in the cycling of nutrients in ecosystems. They decompose (break down) dead animals and plants as well as the urine and faeces produced by animals, and they return the resulting chemicals to the soil and air. Without microbes, the soil would become depleted of nutrients and plants would soon cease growing.

INVESTIGATION 15.4

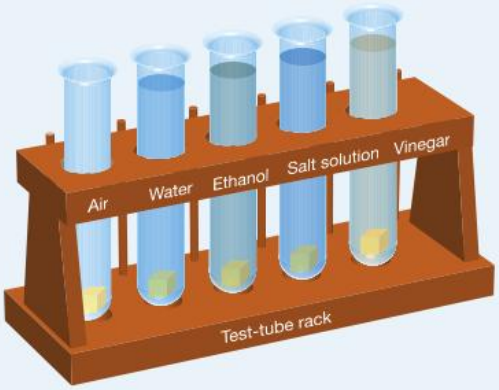
Preserving apples

AIM: To test substances for their effectiveness as food preservatives

You will need:

small apple cubes (peeled)
test tubes
range of solutions to test for their effectiveness as food preservatives (e.g. water, ethanol, sugar solutions of different concentrations, vinegar, salt solutions of different concentrations)

- Place one apple cube in each test tube.
- Do not add anything to test tube 1.
- In each of the other test tubes, pour one of the solutions you are testing. For example, you could put water in test tube 2 and ethanol in test tube 3.



Discussion

1. Write an aim for this experiment.
2. Design a table to record your results. You will be recording your observations for each apple cube each lesson for the next two weeks.
3. In each lesson, record whether each piece of apple has changed. Take note of the colour, the presence of mould and any other signs of decay.
4. At the end of two weeks, write a conclusion for this experiment.
5. Why do you think certain substances were able to preserve the food (stop the food from decaying)?
6. List some examples of foods that are preserved using:
   (a) salt
   (b) sugar
   (c) alcohol
   (d) vinegar.

HOW ABOUT THAT!

In the future, the dentist's drill might be replaced by a spray of bacteria or a vaccine. Tooth decay is caused by a bacterium called *Streptococcus mutans*. A vaccine against this bacterium would greatly reduce the incidence of tooth decay. Certain bacteria can prevent the growth of *S. mutans*. Mouthwashes or sprays that contain good bacteria may one day be used to control tooth decay.

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. **Identify** some human diseases caused by bacteria.
2. Name two plant diseases caused by bacteria.
3. **Outline** the role of bacteria in the manufacture of coffee and chocolate.
4. **Identify** the bacteria that cause tooth decay.
5. **Outline** why food decays more slowly in the fridge.
6. Name five foods that are produced using bacteria.
7. **Outline** the essential role bacteria play in the environment.

Think

8. **Propose** why it is important to wash your hands after using the toilet and before eating.
9. Design an experiment to investigate which conditions cause bread to go mouldy fastest.
10. Yeast is a fungus that converts glucose to alcohol and carbon dioxide gas.
    (a) Yeast is added to bread dough to make it 'rise'. As the dough rises it expands and small bubbles of gas are trapped in the dough, giving bread its typical texture. **Explain** what causes the dough to rise.
    (b) Suggest why baked bread does not contain alcohol even though alcohol is produced as the dough rises.
    (c) Yeast is also used to produce alcoholic drinks including wine. When yeast is added is added to crushed grapes, alcohol is slowly produced until the concentration of alcohol reaches about 15%. Suggest why higher concentrations of alcohol are not usually achieved in this process.

Investigate

11. Long-life milk lasts for months at room temperature until it is opened. Find out the process involved in making milk 'long life'. Does the process affect the nutritional value of the milk in any way?
12. Write a report about a bacterial disease. Include information about the cause, symptoms and treatment of the disease.
13. Find out what probiotics are and why some people supplement their diet with probiotics.

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Complete this digital doc: Worksheet 15.5: The good and the bad (doc-12487)

15.7 Call in the decomposers

15.7.1 What are decomposers?



After organisms die, the decomposers are responsible for breaking down their bodies and recycling the atoms that make them up. Decomposers include worms, some insects, bacteria and fungi. They feed on the chemicals that make up the dead organism and convert them into other chemicals. By doing this, they return the nutrients that make up the dead organisms to the soil and the atmosphere, where they can be taken up by plants and other living things.

Decomposers can also break down some of the rubbish humans produce. Things that can be broken down by decomposers, such as paper and food scraps, are said to be biodegradable, whereas substances like plastic or foam that cannot be broken down by microbes are said to be nonbiodegradable.

HOW ABOUT THAT!

An entomologist is a scientist who studies insects. Sometimes entomologists are asked to provide information to help solve crimes. After a person or animal dies, insects are attracted to the corpse and feed on it. They lay their eggs in the corpse, and larvae eventually emerge from the eggs and develop into adult insects.

Over time, different types of insects colonise the body. By looking at the types of insects and what stage of their life cycle they are at, it is often possible to work out the time of death. It is sometimes also possible to find out other information about the crime from the types of insects that have colonised the body. If a body spent some time in a dry cool area before being buried in dry sandy soil, the insects living on it would be different from those if it had been buried in dry sandy soil straight after death.

Professor Jerry Butler is a real-life entomologist. He is shown here examining hairy maggot blowfly larvae retrieved from a murder victim.



15.7.2 Flies and maggots



Flies lay their eggs on dead and decaying animals. The eggs hatch into **larvae** that are called maggots. The maggots can quickly eat away large parts of a dead animal. The maggots grow up to become flies, which lay eggs somewhere else, or become food for other animals. This recycles the nutrients from the dead animal back into the ecosystem.

15.7.3 Worms



Worms are very effective recyclers. Worms eat just about anything and can do so quickly. They are especially good at recycling our food waste. Worms are found underneath dead organisms in the soil. They feed on animal and plant remains, recycling them into nutrients for plants.

Bacteria



Bacteria can grow on anything — dead or alive. They grow and reproduce very quickly. Bacteria reproduce by simply dividing in half. Bacteria feed on decaying material to help break it down and recycle nutrients for other animals. This photograph of bacteria was taken using an elecron microscope.

Fungi



Mushrooms and toadstools are fungi that feed on dead material. Another variety of fungus is called **mould** and looks 'fuzzy'. Fungi grow microscopic threads into the food they are feeding on. These threads help to break down the dead organism. Fungi may become food for other animals, or they may decay. This allows the nutrients to be recycled back into the ecosystem.

15.7.4 Cycles in nature

Decomposers play an important role in the cycling of nutrients. They are involved in the carbon cycle as well as the nitrogen cycle.

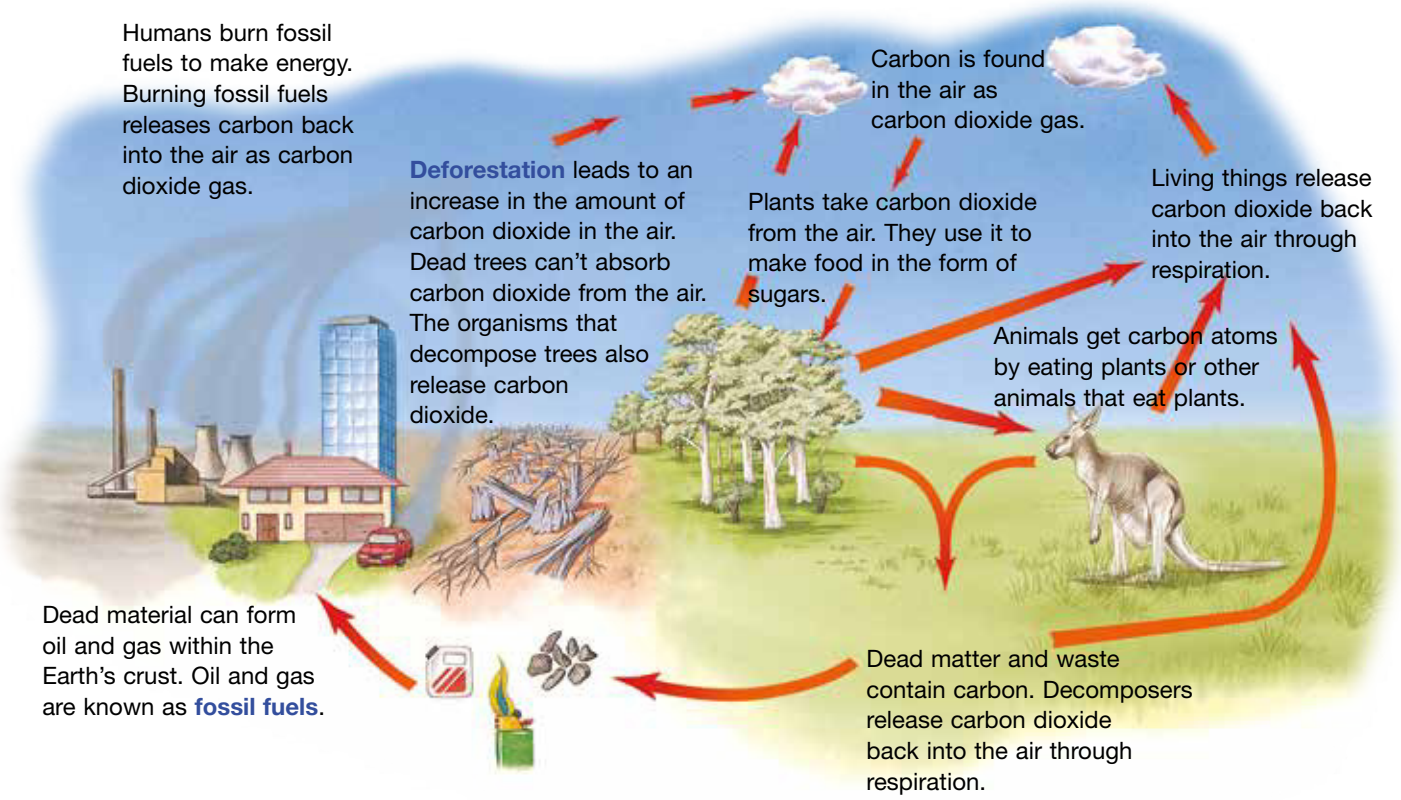
The carbon cycle

Carbon enters ecosystems via plants. As plants carry out photosynthesis, they take in carbon dioxide from the air and convert it to glucose. The glucose is, in turn, converted into other carbon compounds that make up the plant. When animals eat plants they take in the carbon compounds. Some of the carbon is returned to the atmosphere in the process of respiration, and some is stored in the proteins, fats and other compounds that make up their bodies. Bacteria break down the bodies of dead animals and plants and return the carbon back to the atmosphere so that it can be taken up by plants again. Under the right conditions the remains of living things can be very slowly converted to fossil fuels such as coal, oil and gas. This process also relies on the action of bacteria and takes millions of years. Burning the fossil fuels releases the carbon back into the atmosphere in the form of carbon dioxide gas.

Carbon atoms are found in the air, soil, rocks, in oil and gas below the Earth's surface, and in all living things. The number of carbon atoms on Earth always remains the same. When living things use carbon

atoms, the atoms don't just disappear. They are recycled. The diagram below shows this. It also shows that humans can impact on natural recycling processes. Burning of fossil fuels to produce electricity and run cars and other devices is adding carbon dioxide to the atmosphere at a faster rate than plants can take it up. Carbon dioxide levels are steadily increasing.

The carbon cycle



Upsetting the balance

Fossil fuels take a very long time to form. Over recent times humans have been digging up fossil fuels and burning them at a rapid rate to produce electricity, heat homes, run cars and provide energy for many industries. Carbon dioxide is being released in the atmosphere at a faster rate than plants can take it up. This has led to an increase in the levels of carbon dioxide in the atmosphere (see page 601 for further information). Carbon dioxide is a greenhouse gas. It traps heat from the sun in the Earth's atmosphere. There is increasing concern among scientists that allowing the levels of carbon dioxide and other greenhouse gases to continue to rise may result in irreversible changes to the climate.

15.7.5 The nitrogen cycle

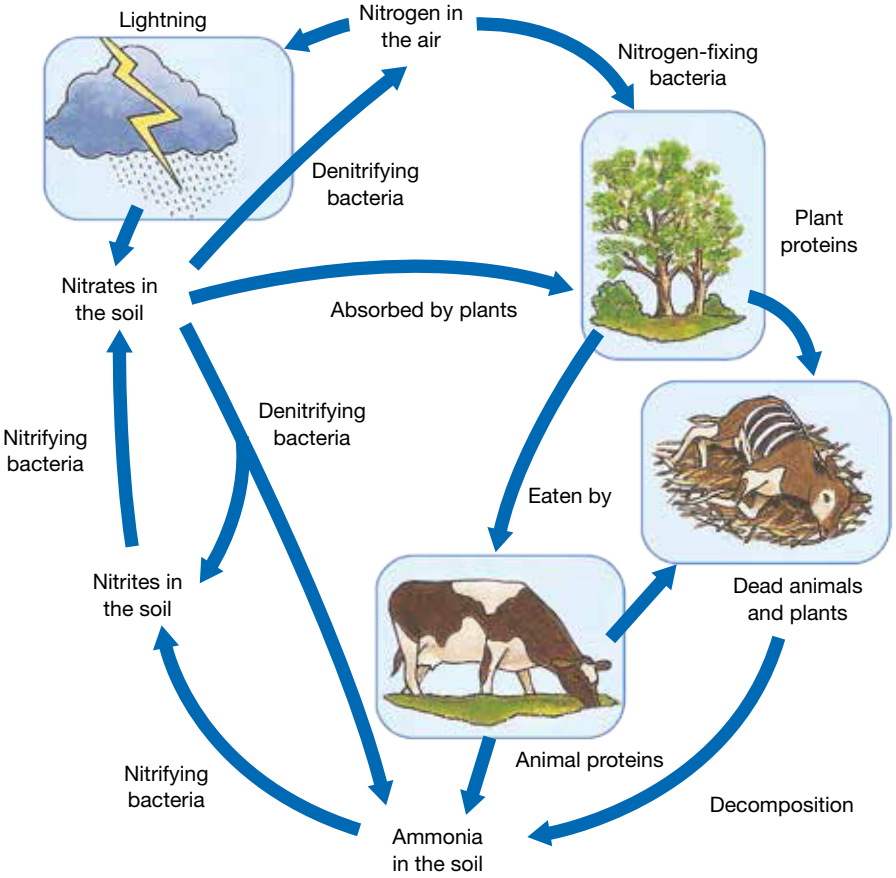
Plants need to take in nitrogen to make protein. In the atmosphere, 78 per cent of the air consists of nitrogen gas, but plants cannot take in nitrogen in this form. Certain bacteria called nitrogen-fixing bacteria can convert the nitrogen in the air into a form that plants can absorb. Some plants, including clover and lucerne, harbour these bacteria in nodules on their roots. Different types of bacteria found in soil break down dead plants and animals, as well as their waste, to make more nitrogen available to plants. When animals eat the plants, they in turn take in the nitrogen-containing protein that the plants manufactured.

‘Where even the Earth is melting’

New data suggest that the world is on the cusp of a ‘tipping point’ into dangerous climate change. Scientists have been measuring the amount of methane released from melting permafrost in the Arctic. Permafrost is frozen soil. It contains organic matter derived from the ancient remains of living things. In the frozen state, the organic matter in the permafrost does not decompose. Increases in global temperatures have resulted in the thawing of permafrost in some areas of the Arctic. This has allowed bacteria to get to work and break down the organic matter, releasing large quantities of methane gas as well as carbon dioxide. Both these gases are greenhouse gases. Methane is even better at trapping heat in our atmosphere than carbon dioxide. Previously, scientists had assumed that the quantities of greenhouse gases released by permafrost were not very significant. It turns out that thawing permafrost may in fact have a very significant impact on our future climate. NASA scientists are carrying out experiments to find out how quickly the permafrost is thawing and the rate at which greenhouse gases are being released from the permafrost.

Source: Based on an article by Ben Cubby, *Sydney Morning Herald*, 27 November 2012.

The nitrogen cycle



INVESTIGATION 15.5

Investigating decomposition

AIM: To investigate how different materials decompose

You will need:

samples of different types of plant matter, such as grass clippings, leaves, vegetable peels, cuttings from a shrub or hedge, straw
250 mL beakers
cling wrap
temperature probes and a data logger

- Half-fill each beaker with a different type of plant matter.
- Cover each beaker with cling wrap.
- Connect the temperature probes to the data logger (one probe for each beaker) and set up the data logger to collect a temperature reading every 10 minutes for 24 hours.
- Push each temperature probe into a different type of plant matter (you will need to pierce a hole in the cling wrap) and start the data logger.
- After 24 hours (or during your next Science lesson), collect the results from the data logger and observe the plant matter in each beaker.

Discussion

1. Study the graph produced by the data logger. Which type of plant matter released the most heat as it decomposed?
2. Describe some improvements that could be made to this experiment to make it a fairer test?
3. What are the advantages of using temperature probes connected to a data logger rather than thermometers for this experiment?
4. Apart from the rise in temperature, what other evidence is there that the plant matter has started to decompose?
5. Microbes decompose the plant matter. Explain why keeping the plant matter moist accelerates its decomposition.

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.

Remember

1. **Recall** four groups of decomposers.
2. **Define** the terms 'biodegradable', 'maggot' and 'larvae'.
3. How do bacteria reproduce?
4. List two examples of fungi.
5. **Identify** three processes that release carbon dioxide into the atmosphere.
6. **Identify** a process that removes carbon dioxide from the atmosphere.
7. Name two greenhouse gases.
8. **Outline** why thawing permafrost releases large quantities of methane gas.
9. What percentage of our atmosphere consists of nitrogen gas?
10. **Describe** the role of nitrogen-fixing bacteria in ecosystems.
11. **Outline** why an entomologist might be called upon when a body is found to help determine the time of death.

Think

12. The release of greenhouse gases from thawing permafrost is a natural process, although human action has contributed to the melting of permafrost. **Explain** why.
13. **Outline** why it is important to find out how quickly permafrost is thawing.
14. Maggots look a bit like small worms but they actually belong to a very different group of animals. Worms belong to a group of invertebrates called the annelids. Which group do maggots belong to? (*Hint:* Think about what the maggots will become.)
15. In the early sixteenth century it was widely believed that maggots formed naturally from rotting meat.
    (a) If you bought a piece of meat from the butcher and kept the meat inside a plastic bag, would maggots appear on the meat after some time? **Explain** your answer. (Assume that no flies came in contact with the meat before it was sealed inside the bag.)
    (b) Would the meat in the plastic bag eventually decay? **Explain** your answer.
    (c) **Describe** three ways that the meat could be prevented from rotting.

Research

16. Find out how to set up a worm farm. Design a pamphlet explaining how to set up a worm farm. Include information about the type of household rubbish that can be fed to worms.
17. Click on the **Permafrost** weblink in the Resources tab to watch a video of scientists talking about the thawing of permafrost.

learnON RESOURCES — ONLINE ONLY

Complete this digital doc: Worksheet 15.6: Cycles in nature (doc-12488)

15.8 Extreme weather ahead

15.8.1 Drought

The Australian continent is a land of extremes. Years of drought can be broken by torrential rain that results in flooding. Bushfires and cyclones are also regular occurrences. These are natural events, although there is increasing concern that global warming might increase the frequency and intensity of extreme weather events. Scientific research and technological advances can help us predict and prepare for floods, droughts and cyclones, and manage their impact on ecosystems.

Australia is the driest continent on Earth. Areas away from the coast receive very little rainfall and much of central Australia is so dry that the land is not suitable for farming. Even near the coast it is often necessary to **irrigate** (water) crops. In addition to this, Australia regularly experiences periods of drought. Severe droughts impact on farming and the economy as crops fail and livestock have insufficient feed. In towns and cities, dams dry up and water restrictions are put in place to conserve the remaining water.

Droughts also impact on ecosystems. During periods of drought there is more soil erosion and bushfires are more frequent. When creeks and rivers dry up, the living things that live in or around them often do not survive. In turn, the animals that feed on these are also affected. Species of plants that are not drought tolerant may die and be replaced by more drought-tolerant species. This will, in turn, affect the types of animals that live in a particular area. Fifty thousand years ago, much of Australia was covered with lush rainforests full of plants with large soft leaves. The Australian climate became drier over time. The rainforest plants were not suited to the dry conditions and died out. Plants with smaller, harder leaves were better suited to the dry conditions and replaced the rainforest plants. The plants covering much of Australia today are ideally suited to dry conditions.

Little grass grows in times of drought, and grazing animals run out of food.



15.8.2 Floods

When rain does fall in Australia, it tends to fall over a short period of time, resulting in flooding. Floods impact on agriculture. Livestock may drown and crops can be destroyed. When a town or city is flooded, the damage to property can be very costly to repair. In some cases, lives may be lost, and diseases may spread as sewerage systems overflow and mix with the floodwaters. Floods also impact on the natural

environment. Vegetation may die if it remains under water for long periods of time, and top soil is moved from one area to another by the floodwater. Weeds that are tolerant of flood conditions might spread after a flood event. Flooding can also flush out excess salt, chemicals and pollution from the soil.

Floods can also have positive effects though. Floodwater can seep deep into the ground and provide water for plants long after the flood has receded. Fertile mud can be deposited over the floodplain. Ancient Egyptians exploited this by growing crops on the banks of the Nile River. The flooding pattern of the Nile River was reasonably predictable. Crops would be planted in the nutrient-rich soil after a flood had retreated and would need to be harvested again before the next flood. In deserts, short periods of heavy rain resulting in flooding may provide the only opportunity for plants to bloom briefly.

A flooded street in a suburb of Brisbane in January 2011



15.8.3 Cyclones

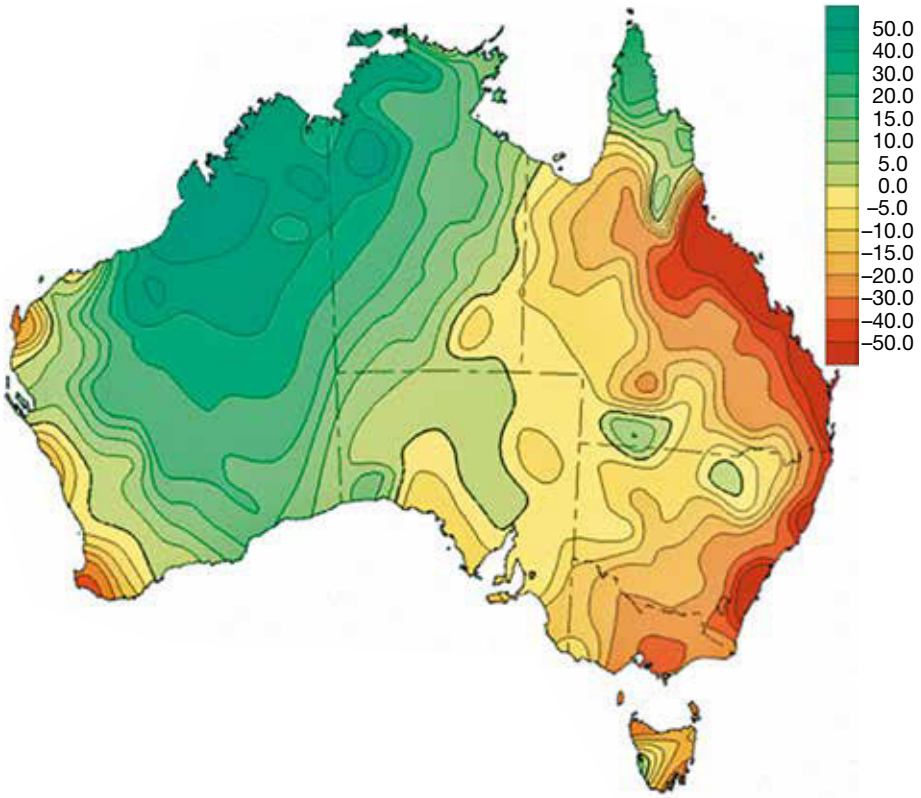
Cyclones develop when a low-pressure system forms over the warm oceans of the tropics. When cyclones develop in the Southern Hemisphere, very fast winds spin in a clockwise direction and thunderstorms are formed. In the northern parts of Australia, cyclones are common during the summer months and can cause very costly damage. On Christmas Eve of 1974, cyclone Tracy hit Darwin and destroyed most of the buildings. Thousands were left homeless and 71 people died. In 2006, cyclone Larry caused significant damage to buildings and infrastructure in areas near Cairns. It also had a significant impact on farming as many crops, including banana crops were destroyed by the cyclone.

The heavy rainfall associated with cyclones can cause flooding. Cyclones also affect ecosystems in other ways. Trees may be uprooted or have their branches broken by strong winds.

15.8.4 The impact of global warming on weather patterns

The drought experienced at the start of this century was the worst in Australia's recorded history. Some climate experts are blaming global warming while others argue that Australia's climate has cycled through periods of drought and flood for many years before the world started to warm up. All agree though that further global warming is likely to permanently change rainfall patterns and is likely to result in an increase in the frequency of extreme weather events. The southern parts of Australia, where most people live, are set to become drier. This will impact on farming and affect water supplies for cities. Creative solutions are urgently needed.

Between 1950 and 2008, rainfall patterns have changed significantly in Australia. Most of the east coast of Australia has experienced a decrease in rainfall of more than 50 mm every 10 years, whereas the northwest coast has experienced increased rainfall. This trend is predicted to continue.



HOW ABOUT THAT!

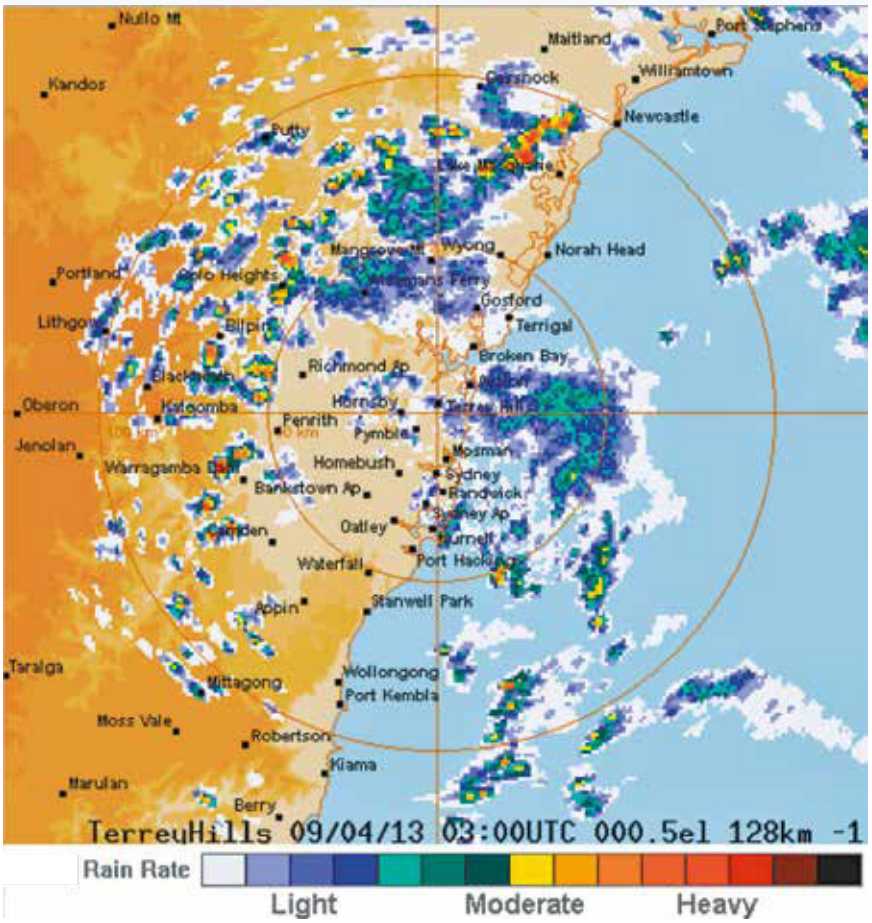
- A team of scientists led by Dr Jim Wallace was on the ground to investigate the aftermath of cyclone Larry, which hit north Queensland in 2006, and cyclone Monica, which affected the Cape York area and Northern Territory in the same year. They collected data to record the effect of the cyclones on natural ecosystems. Floods resulting from cyclone Larry flushed pollutants and sediments into the Great Barrier Reef lagoon. This may affect the health of the reef.
- Dr Louise Shilton studied the impact of cyclone Larry on populations of flying foxes (fruit bats). Immediately after the cyclone, tens of thousands of spectacled flying foxes had gone missing from the area. There were eyewitness accounts of bats flying off before the cyclone hit and only a few dead flying foxes were found after the cyclone. Dr Shilton had a hunch that the bats had relocated temporarily and would be back when the native trees started to produce fruit. She asked members of the public to report sightings of the bats to find out more about the new habitats the bats had chosen for themselves. Dr Shilton's hunch proved to be correct. The fruit bats appear to have made their way back to the area that was devastated by the cyclone.

Spectacled flying foxes were observed to fly off ahead of cyclone Larry.



15.8.5 Minimising the impact of drought, flood and cyclones on ecosystems

In this radar image, rainfall is shown as coloured patches.

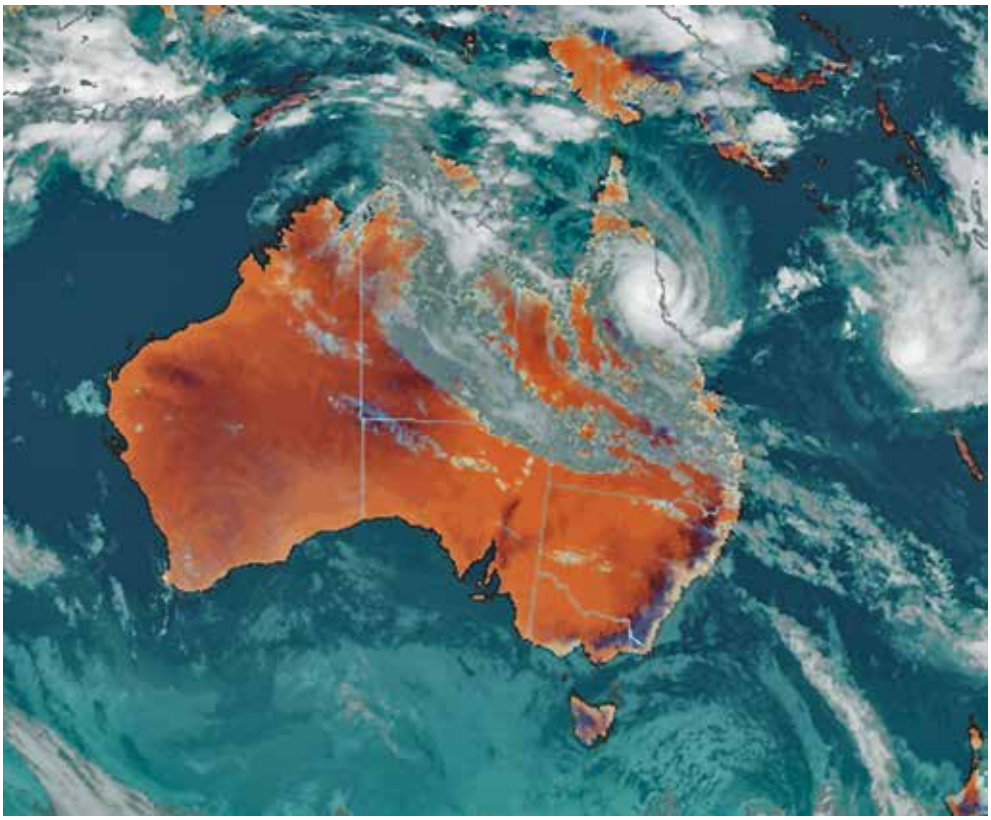


Understanding weather patterns and predicting the weather accurately can minimise the impact of extreme weather events on ecosystems. To predict the weather, measurements of the current conditions are taken, including temperature, air pressure, rainfall, wind speed and direction, and cloud cover. Weather forecasters used to rely on these data and previously observed patterns to make predictions. For example, rapidly increasing cloud cover is a strong indicator that rain is likely in the next few hours. The use of computers has increased the accuracy of forecasts and allowed predictions to be made further into the future. The data collected from the various weather stations are fed into a computer, and software that uses complex mathematical modelling is used to analyse the data, identify trends and make predictions.

The use of radar and satellite images has contributed to increasing the accuracy of weather forecasts. When you make a loud sound in an empty room, the sound is reflected back by the walls and you hear an echo. Radars work in the same way. They send out microwave radiation into the air, then 'listen' for an echo. The microwaves are reflected back towards the radar by objects in the air, including raindrops and hailstones. If the rain is close, the echo is detected by the radar very quickly. An echo from distant rain takes longer to reach the radar. The data are then interpreted by a computer, and images such as the one above are produced. These images are particularly useful for predicting when and where heavy rain and storms will hit.

Satellite images provide information about cloud cover and the direction in which clouds are moving. The satellites used to take these photos orbit the Earth at a low altitude. There are various sensors on board the satellites. Some detect infra-red radiation (heat). Most clouds are cooler than the underlying land or ocean, so they show up as cooler areas. Visible-light detectors produce images that show what the Earth actually looks like under the satellite. The satellite images shown in weather reports are usually a composite image that combines both infra-red and visible-light data. Cyclones are easily identified in such images as swirling masses of clouds and can be tracked over time.

Satellite image showing cyclone Larry on 20 March 2006



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.

Remember

1. **Outline** why it is necessary to irrigate crops in many parts of Australia.
2. **Describe** the impact of droughts on people and the environment in Australia.
3. **Outline** how the vegetation of Australia has changed over the past 50 000 years.
4. **Explain** why floods can be very costly to individuals, businesses and governments.
5. **Outline** the impact of floods on ecosystems.
6. **Explain** why cyclones are frequent in north Queensland.
7. **Outline** the likely impact of global warming on rainfall patterns in Australia.
8. **Describe** two examples of technological advances that have improved our ability to predict the weather.

Skill builder

9. Study the map on page 616.
   (a) **Identify** the parts of Australia that experienced the greatest reduction in rainfall between 1950 and 2008?
   (b) Which parts of Australia have not experienced a significant change in rainfall patterns?
   (c) If the trend in changing rainfall patterns continues, what is likely to be the long-term impact on farming in Australia?
10. The map opposite shows the path of cyclone Larry. The numbers show the intensity of the cyclone.
    (a) When did the cyclone cross the cost of north Queensland?
    (b) When did the cyclone reach its maximum intensity?
    (c) **Explain** why the cost of repairs following a cyclone depends not only on the intensity of the cyclone but also on the path that it follows.

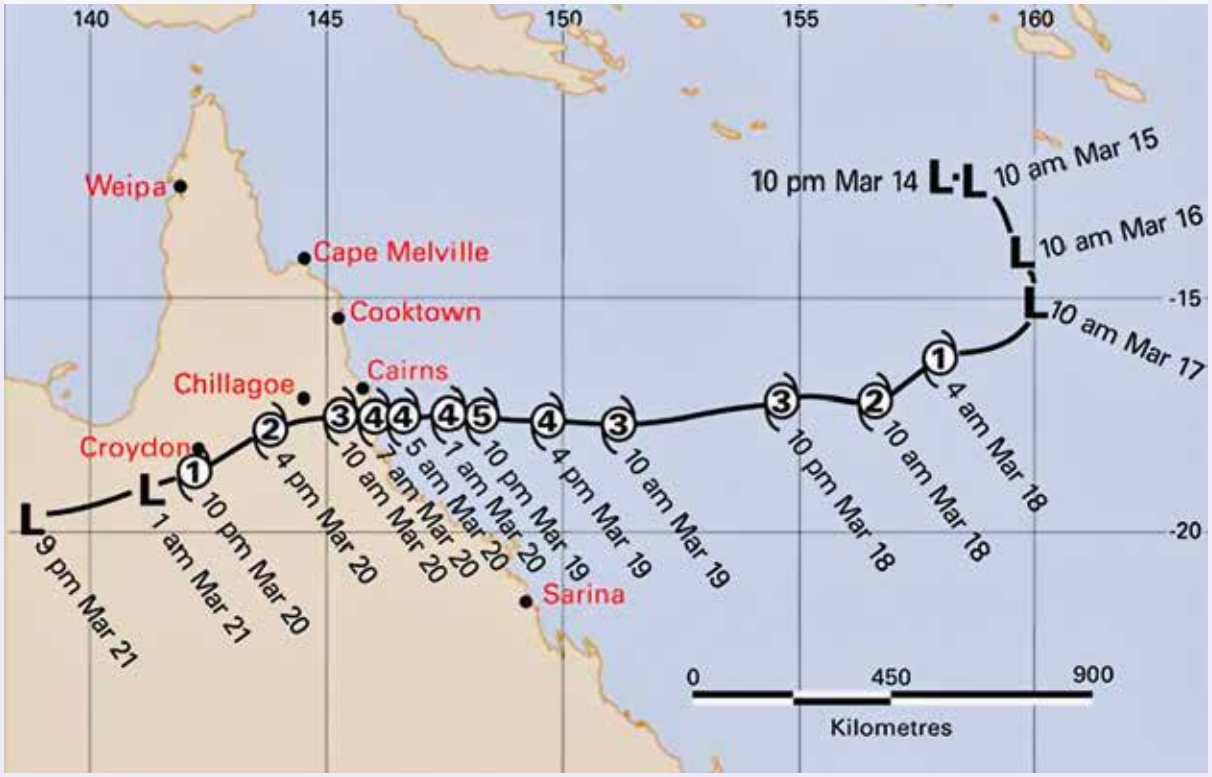
Think

11. **Explain** why cyclones in north Queensland can increase pollution levels near the Great Barrier Reef.
12. The bats studied by Dr Shilton were observed to fly away ahead of the cyclone. It has been suggested that they detected the drop in air pressure and this warned them of the approaching cyclone. Design an experiment to test whether spectacled flying foxes can detect variations in air pressure and if this affects their behaviour. (*Note:* The experiment you design should not cause harm to the bats.)
13. **Explain** why improved weather predictions can reduce the impact of extreme weather events.

Research

14. Find out what a water desalination plant is and **discuss** whether it was a good idea to build one at Kurnell in Sydney.
15. Search EBSCO or the archives of a major newspaper to locate a news article about a recent Australian extreme weather event (a recent storm, cyclone, flood, drought, heatwave etc.). **Summarise** the key points in the article.
16. Use the **New inventors** weblink in the Resources tab. Browse the inventions by category and select the category 'environment'. Make a list of at least five Australian inventions that are aimed at conserving water, recycling water or obtaining fresh water from sea water.

Tracking cyclone Larry



learnon RESOURCES — ONLINE ONLY

Watch this eLesson: Global warming in Australia (eles-0057)

15.9 A fiery start

15.9.1 Indigenous Australians and fire

It is believed that Indigenous Australians first arrived in Australia over 40 000 years ago and successfully managed the land. They used very different hunting and gathering practices from those of Europeans. While Aboriginal people did have significant impact on the Australian environment, their lifestyle was sustainable and allowed resources to renew.

Some of the ways in which Indigenous people cared for their land included:

- moving from place to place rather than staying in the same location. This ensured that the plants and animals they fed on had a chance to replenish.
- eating a wide variety of food so that no single food source was depleted
- leaving enough seeds to ensure that plants could regenerate
- leaving some eggs in a nest when collecting
- not hunting young animals or the mothers of young animals
- not allowing particular members of a group to eat certain foods. This ensured that a wide variety of food was eaten and that 'taboo foods' were not depleted.
- leaving the land to recover for a period of time after harvesting a crop, such as bananas. This allowed time for the crop to regenerate and nutrients to return to the soil.



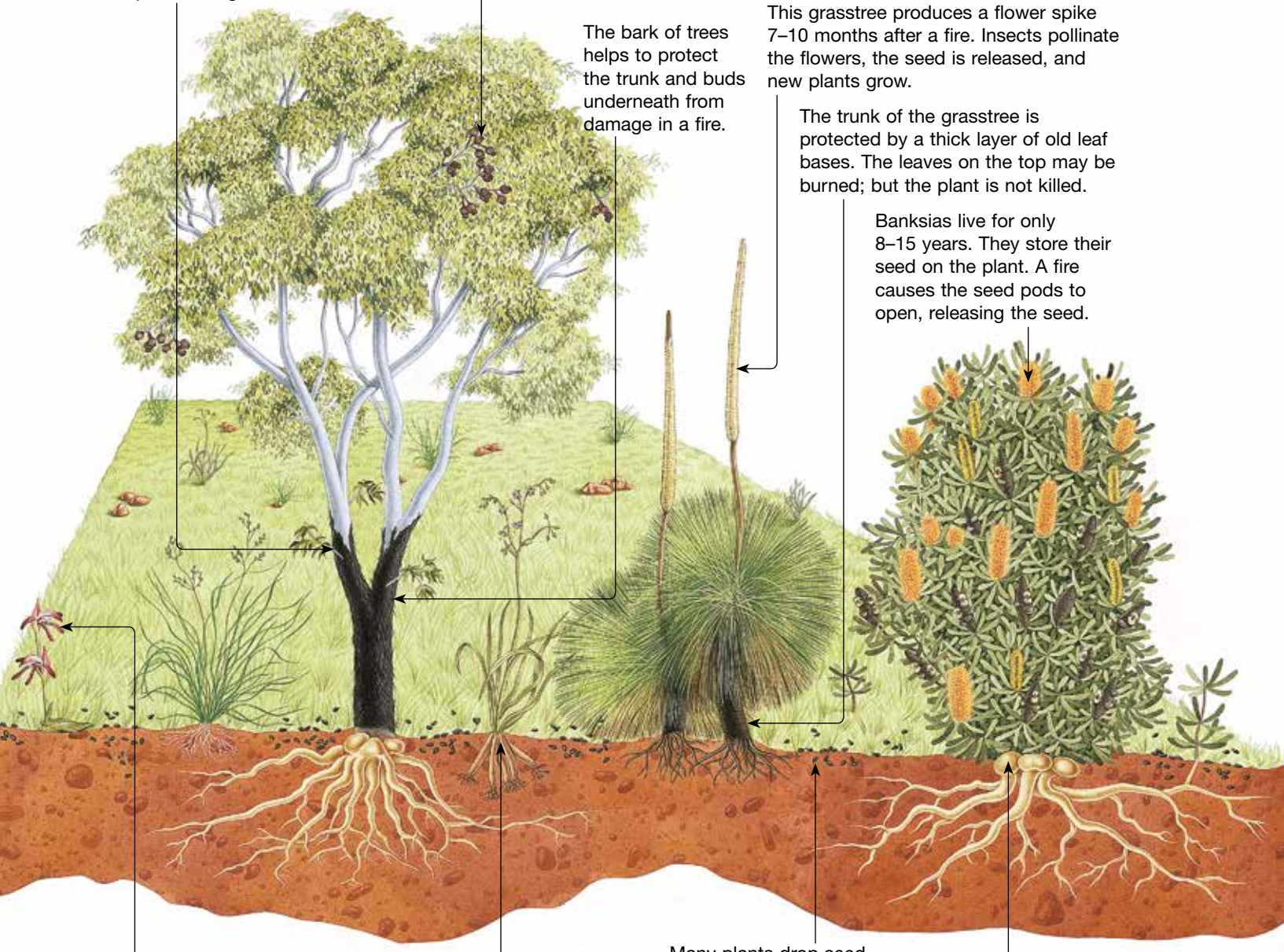
Using fire

One way that early Indigenous Australians affected the environment significantly was through their use of fire. Fire was used for hunting. Setting fire to grassland revealed the hiding places of goannas, and possums could be smoked out of hollows in trees. Fire was also used to clear land. The grass that grew back after the fire attracted grazing animals, which could be hunted more easily.

Over time, some species of plants that were sensitive to fire became extinct whereas the plants with adaptations that allowed them to survive a fire or regenerate rapidly after a fire became more common. Adaptations are features that help an organism survive in its environment. Some modern-day species such as the banksia are not just well adapted to frequent bushfires; they actually need to be exposed to the high temperatures of a fire for their seeds to germinate.


Crown bushfires spread through the treetops or 'crowns' of forests. Before long, a wide blanket of forest is fully ablaze.
Australia's eucalypt forests not only tolerate fire but also need it in order to survive! The seeds of some eucalypts need the heat of a bushfire to be able to open and grow. The low moisture content of eucalypts means they ignite and burn easily. Their fibrous bark is highly combustible.
What was the flank or side of a bushfire can become the new fire front if there is a wind change.
Special helicopters can scoop up to 9500 litres of water in 45 seconds and dump the whole lot in just 3 seconds.
Dry forests provide plenty of fuel. Surface bushfires quickly ignite dry, flammable grass, twigs and branches on the ground.
By using the wrong building materials, planting eucalypts close to the house and stacking firewood against the house, people can actively contribute to the spread of a bushfire.
A firebrand is burning fuel that is pushed ahead of the fire front by the wind. Firebrands have been known to travel kilometres from their original source. A spot fire is a new bushfire started by firebrands.
Properties are more likely to survive if gutters are clear of leaves, lawns and shrubs are trimmed, and there is access to water and hoses. People who defend their houses must cover up with cotton or woollen clothing.

Many Australian plants have adaptations that enable them to cope with frequent fires or regenerate after a bushfire.



Eucalypts have buds underneath the bark. After a fire these epicormic buds sprout new green shoots.

Eucalypts store some seeds on the plant. Eucalypts have woody gumnuts that protect the seed from the heat. After a fire, the seed pods dry out and open. The seeds fall into the ash and germinate.

The bark of trees helps to protect the trunk and buds underneath from damage in a fire.

Fire causes many grasses to flower. This grasstree produces a flower spike 7–10 months after a fire. Insects pollinate the flowers, the seed is released, and new plants grow.

The trunk of the grasstree is protected by a thick layer of old leaf bases. The leaves on the top may be burned; but the plant is not killed.

Banksias live for only 8–15 years. They store their seed on the plant. A fire causes the seed pods to open, releasing the seed.

Many plants flower as a result of fire. The red-beak orchid flowers only in the first season after a fire.

Grasses have their growth tissue at the base of the plant. When the top burns off, the heat rises and the growth area is protected from damage. Grasses can then regrow quickly after a fire.

Some plants, such as lilies, have tubers under the ground. If the top is burned off, they use the energy stored in the tubers to start growing again.

Many plants drop seed that is then stored in the soil. The heat of a fire may crack the hard coating of wattle (acacia) seeds and allow them to germinate. The chemicals in the ash or the smoke may also cause germination. In Tasmania, wattle seeds that are 300–400 years old have been found in soil, just waiting for a fire.

Many plants, such as eucalypts and banksias, have swollen parts on their roots called **lignotubers**. These are protected from the fire by the soil. Lignotubers contain many buds. After a fire they send up new shoots.

15.9.2 Reducing the impact of bushfires

Large wild fires such as occurred in Victoria in 2009 can have devastating consequences including loss of lives and damage to property. They can also impact on ecosystems. As the bush burns, animals become victims of the flames or must flee, and habitats are destroyed. One way of reducing the frequency and severity of wild fires is through regular back-burning. This involves deliberately setting fire to vegetation when temperatures are low and the winds are calm to minimise the chance of the fire spreading out of control. Controlled burning removes highly flammable vegetation that acts as fuel for bushfires.

The extent to which back-burning should be carried out is controversial. If not properly done, it can put properties at risk and needlessly damage forests. It is important that bushfire management strategies, including controlled burning, be based on hard evidence. Project Vesta is led by the CSIRO and involves a number of organisations. It is investigating the behaviour of fires in dry eucalypt forests — the type of forest that covers much of eastern Australia. Findings from the project have already resulted in changes to fire fighting and management practices.

INVESTIGATION 15.6

Fiery seeds

AIM: To investigate the effect of heat on seed germination

You will need:

unopened banksia (or hakea) pods
acacia seeds (silver and black wattle work well)
potting mix
small pots or planting trays

An open banksia pod; the seeds have fallen out.



- Place half the banksia pods and half the acacia seeds in a very hot oven (or in an open fire or barbeque) until the banksia pod has a burnt appearance (your teacher may have done this already ahead of the lesson). Ensure you keep any ash that has been produced.
- Take photos of the banksia pod and the acacia seeds that have been in the oven and the ones that have not been in the oven.
- Collect the seeds from the banksia pod. Take note of the number of seeds collected and plant them.
- Plant the heated and unheated acacia seeds in different pots. Record how many seeds were planted in each pot. If there was any ash produced when you heated the seeds in the oven, place the ash on top of the soil in the pot containing the heated acacia seeds.
- Water the plants as needed and take a photo of each pot in each lesson for the next 4 weeks. Record observations including the number of seeds that have germinated, the height of each seedling and the number of leaves that have formed.

Discussion

1. Describe the impact of heat on the appearance of the banksia pod and acacia seeds.
2. Copy and complete the table below.
3. Construct a column graph to compare the percentage of germinated seeds in each pot after 4 weeks.
4. Construct a line graph showing how the average height of the seedlings in each pot changed over the 4 weeks.
5. Design an experiment to test the hypothesis that it is not just the heat of the fire, but also the chemicals in the smoke from the fire that are important to the germination of banksia seeds.

	Banksia seeds		Acacia seeds (not heated)		Acacia seeds (heated)	
Date	Percentage of germinated seeds (%)	Average height of seedlings (mm)	Percentage of germinated seeds (%)	Average height of seedlings (mm)	Percentage of germinated seeds (%)	Average height of seedlings (mm)

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.

Remember

1. **Define** the following terms: 'sustainable', 'regenerate', 'depleted', 'lignotuber', 'epicormic bud'. Present your answer in a table.
2. How did Aboriginals use fire in their hunting practices?
3. **Outline** how grasstrees respond to fire.
4. **Describe** the adaptations of eucalypt seeds to frequent fires.
5. **Outline** how controlled fires can be used to manage the risk of wildfires.

Think

6. **Explain** why leaving eggs in a nest is more sustainable than collecting all the eggs.
7. Indigenous people avoided hunting young animals. Similarly, today, there are regulations that apply when fishing. Fish below a certain size must be thrown back in the ocean. **Explain** how this makes fishing more sustainable.
8. Design a fair experiment to compare the amount of heat released when burning different types of native leaves. (*Hint:* Use the heat released by the burning leaves to heat water.)
9. Use the **CSIRO bushfire research** weblink in the Resources tab to investigate some of the bushfire research carried out by CSIRO scientists.

learnON RESOURCES — ONLINE ONLY

Explore more with this weblink: CSIRO bushfire research

15.10 Using science to improve agricultural practices

Science as a human endeavour

15.10.1 Agricultural ecosystems

Early humans hunted wild animals and gathered fruit and other plant parts from the natural environment. Thousands of years ago, humans began to cultivate crops and domesticate animals. Through trial and error, agricultural practices were developed. Today, science is contributing to improvements in these practices to increase crop yields, produce animals with desirable characteristics and minimise the impact of farming on natural ecosystems.

One purpose of agriculture is to turn as much of the energy in sunlight as possible into chemical energy in particular crops or pasture plants for animals. To do this, it is necessary to interfere with the food web that includes the selected organism. This often also requires clearing forests or removing other organisms that may compete for resources and hence lower yields. Such activities have led to the destruction of many natural ecosystems. The development of agriculture has caused drastic environmental changes in many ecosystems on our planet.

Monocultures

Farms usually grow very large areas of only one type of plant. For example, in some regions there are thousands of hectares planted only with wheat, while in other regions thousands of hectares are covered with grapes, sugar cane or another single crop. Such crops are called monocultures.

Most crops are monocultures; only one type of plant is grown.



At the end of each growing season, crops are harvested, processed and delivered to shops and supermarket shelves for the consumer. There is little natural decomposition of dead material in fields, and the soil may be exposed to the effects of wind and rain for a certain period of the year. These factors combine to remove valuable nutrients from the soil. Fertilisers are then added to the soil to replace the nutrients removed by harvesting and not replaced by decomposition. Some of these fertilisers may end up in waterways, where they add large quantities of nitrogen and phosphorus to the water. This may result in a condition known as eutrophication, where algae grow rapidly and then decay, using up the oxygen in the water.

15.10.2 Controlling trouble?

Organisms that compete for resources or potentially lower the yield of a crop are considered to be pests that need to be controlled. Pest may be managed through the use of chemical control or biological control.

Chemical methods of control include the use of pesticides such as insecticides, fungicides, herbicides and fumigants. Herbicides kill plants other than the planted crop so that they do not compete for nutrients and water in the soil, and light from the sun. Insecticides are used to kill insects that compete with humans for the food crop.

Modern agriculture provides large amounts of food, but at a cost to the environment.



Although pesticides are still being used in agriculture, their effectiveness on target pest species can decrease over time. Other species within the same ecosystem or food web may also be affected. In some cases, concentrations of non-biodegradable pesticides (such as DDT) can be magnified along the food chain by a process described as **bioaccumulation** or **biomagnification**.

Management of pests through biological control exploits naturally existing ecological relationships. The use of natural predators to control a particular pest is one such example. While some cases of biological control have proven to be successful, others (such as the introduction of cane toads and prickly pear plants) have caused a variety of new problems.

15.10.3 Science to the rescue

Growing the same type of plant in the same field year after year can deplete soil of particular nutrients. It can also increase pest problems as pest populations become established in fields where their preferred food source is grown continuously. One solution is crop rotation: changing the type of crop grown in a field. Crop rotation has been practised by farmers as far back as ancient Roman times. Roman farmers knew that alternating crops of wheat with crops of legumes such as peas, beans or soybeans increased crop yields, but they did not understand why the technique worked.

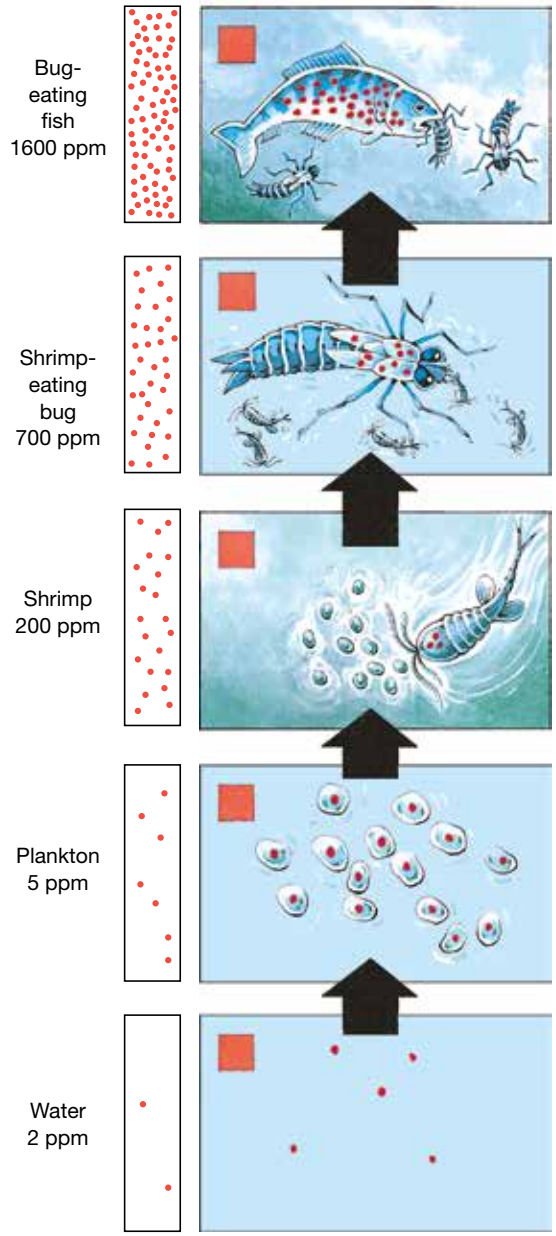
In the nineteenth century it was discovered that nodules (bumps) on the roots of legumes were involved in nitrogen fixation, a process where the nitrogen in the air is converted to a form that plants can use. A Dutch scientist later isolated and cultured the microbes contained in the root nodules.

Scientific investigations have also played a part in determining the ideal patterns of crop rotation. For example, in the US, corn borers are a common pest affecting corn crops. Cultivating corn in a two-year rotation with soybeans can decrease the need for fertilisers but it does little to reduce the population of corn borers. Increased knowledge of the reproductive cycle of the corn borer and well-designed experiments have shown that a four or five-year rotation cycle is an effective way to reduce corn borer numbers.

An understanding of predator–prey relationships can reduce the need for pesticides. Managing farms to encourage the predators of pests rather than keeping them out of crops or killing them can be effective in controlling pests.

Understanding how different types of plants interact can also increase yields and reduce pest populations. Growing certain types of plants together — companion planting — can improve the health of plants. For example, growing rosemary near cabbage plants is thought to deter cabbage moth, and growing marigolds throughout a garden may repel many pests. Controlled experiments to compare the growth of plants with and without their companion plants can provide valuable information to farmers.

Some chemical pollutants such as pesticides can become more concentrated along the food chain.



Growing marigolds throughout a garden may repel pests.



15.10.4 More of the same

Another important way that science has contributed to agriculture is in the development of breeds of animals and plants with desirable characteristics. The main fruit, vegetable and cereal crops grown worldwide and the animals found on farms today are quite different from their wild ancestors. This is often the result of selective breeding. Seeds from plants with desirable characteristics are collected and sown, and animals with valuable features are interbred. The calves produced by a cow that is a good milk producer might be allowed to reach adulthood and breed in the hope that her offspring will also be good milk producers, whereas the offspring of a poor milk producer may be sent to an abattoir before she can reproduce.

When plants produce seeds, the genetic information in the seed is not identical to that of the parent plant. The offspring may have more or less desirable characteristics than the parent plant. Growing plants from cuttings, runners, suckers and tubers are examples of asexual reproduction. There is only one parent plant involved and the resulting plant is genetically identical to its parent.

Wild bananas look very different from those you buy at the shops. The bananas that are grown commercially in Australia are not produced from seeds. They are grown from suckers. A sucker is a shoot-like structure that grows at the base of the parent plant. It can be separated from the parent plant and will grow into a new plant that is genetically identical to its parent. This growing technique produces high yields and ensures that the bananas have the same desirable characteristics as the parent plant. Using a parent plant that produces large, sweet bananas results in new plants that also produce fruit with these features. An unfortunate consequence of this lack of diversity is an increased risk that entire crops can be wiped out by disease or environmental changes. When there is a lot of variation within a species, it is more likely that some of the individual plants will survive when new diseases emerge or the environment changes.

Seedless fruit, including seedless watermelon and grapes, are now commonly produced. Since these fruit lack seeds, they cannot be used to produce the next generation of plants. The plants must be produced from cuttings or some other type of asexual reproduction.

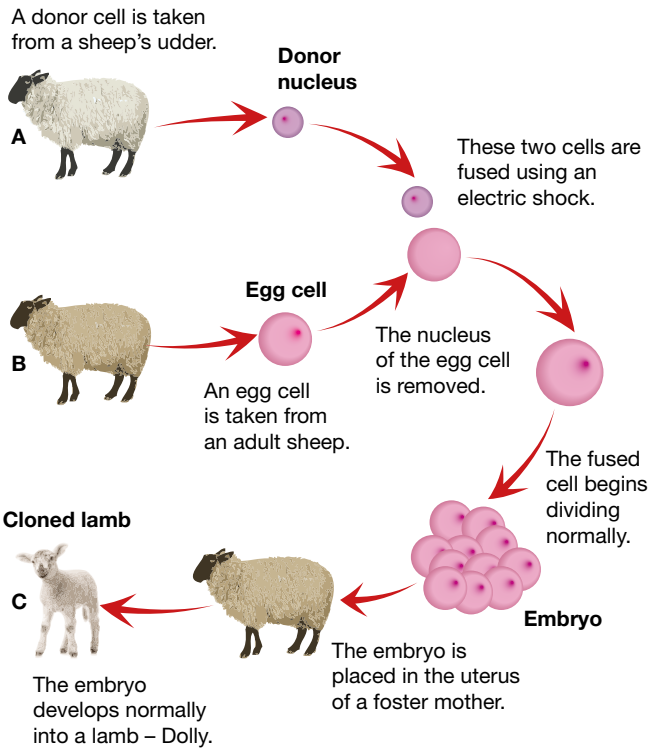
The smaller plant to the left of the larger plant is a sucker. It is genetically identical to the larger plant. Banana plants generally produce a number of suckers. These can be planted to produce new banana plants.



It is also possible to produce animals that are genetically identical to a parent animal by cloning them. Cloning involves taking an egg from an animal, removing the nucleus and replacing it with the nucleus from one of the parent animal's body cells. The egg is then implanted into the womb of either the parent animal or another animal, where it develops until birth. The first farm animal to be cloned was Dolly the sheep in 1997. Cloning is still an experimental technique. Many attempts are usually required before a clone is successfully produced, and the clones tend to die earlier than animals produced naturally. Imagine being able to clone the horse that won the Melbourne Cup last year!

While cloning is not routine practice, other reproductive technologies are used more frequently. Artificial insemination, a process where sperm is collected from a male animal and inserted directly into the vagina of a female animal, is an increasingly common practice. Sperm from a male with desirable characteristics can frozen and transported over vast distances much more easily than the animal that produced it.

How Dolly the sheep was created



INVESTIGATION 15.7

Asexual reproduction in plants

AIM: To investigate various methods of asexual reproduction

You will need:

gas jar
beaker or glass jar
pot
large onion
potato
grass runner
leaf–stem cutting from geranium or impatiens.
(Note: *A leaf–stem cutting is a piece of the plant's stem that is cut just below a joint or growing point and has at least three leaves.*)
leaf from African violet, jade plant or snake plant
rooting medium (this can be purchased from a nursery)

Leaf–stem cutting



- Fill a gas jar almost to the top with water and place the onion in the mouth of the jar so that its base is sitting in the water as shown in the diagram on the opposite page.
- Leave the potato in a dark cupboard.
- Remove the lower leaves from the leaf–stem cutting. Quarter-fill a beaker or glass jar with water and place the cutting in the water.
- Place some rooting medium in a pot. Add water to the rooting medium until it feels moist. Cut a 3 cm section from the leaf of the African violet, jade or snake plant. Stand the piece of leaf upright in the rooting medium.

- Cut a piece of the grass runner. Ensure the section you have cut has at least one growing point. Press the piece of grass runner into the rooting medium (lying flat on the surface).
- Leave all the plant parts undisturbed for two weeks. You may need to top up the water over that time.

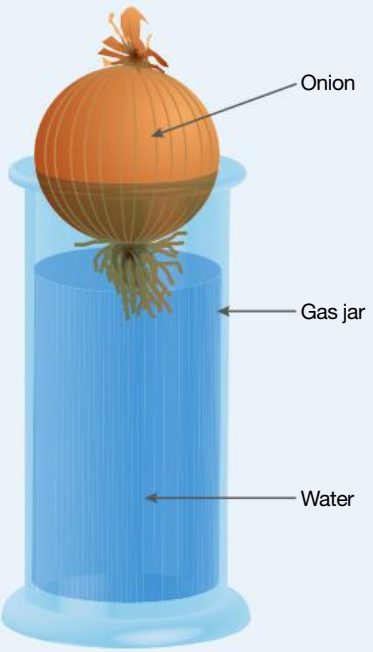
Discussion

1. Copy and complete the table below. You may need to dig the leaf–stem cutting and the runner from the rooting medium and wash them to see what has happened.
2. Explain why each of the examples in the table is a form of asexual reproduction.

Plant part	Description after two weeks	Diagram
Onion		
Potato		
Leaf–stem cutting		
Leaf		
Runner		

3. What are the advantages of growing plants using one of the techniques described in this investigation rather than growing them from seeds?

An onion with its base in water



15.10 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 terms 'crop yield', 'monoculture', 'eutrophication', 'crop rotation' and 'companion planting'.
2. List some desirable characteristics in a:
   (a) hen (b) cow (c) farm dog.
3. **Distinguish** between chemical and biological control of pests and give an example of each.
4. **Outline** the benefits of crop rotation.
5. Legumes can 'fix' nitrogen. **Explain** what this means.
6. List four plant structures that can be used to produce plants that are identical to the parent plant.

Think

7. What are the advantages of cultivating crops and domesticating animals, such as cattle and sheep, rather than relying on hunting and gathering for food?
8. **Explain** why it is often necessary to apply fertilisers to cultivated land whereas plants can survive in natural ecosystems such as rainforests without fertiliser.
9. **Outline** why extensive use of fertilisers can cause eutrophication.
10. Herbicides are used to kill weeds. What is the reason for controlling the growth of weeds on agricultural land?
11. **Explain** the process of bioaccumulation.
12. Lead and mercury are substances that accumulate in living things, as DDT does. Lead is harmful to humans and it can affect brain development in unborn babies and infants. **Explain** why women are advised to limit their consumption of large fish such as shark and salmon during pregnancy.
13. **Explain** how selective breeding could be used to produce very small dogs with large eyes.
14. What are the advantages of producing plants and animals that are genetically identical to their parents?
15. Suggest why artificial insemination is often used in zoos.

Research

16. Use a dictionary or other reference material to **distinguish** between insecticides, fungicides, fumigants and herbicides.
17. Dolly was the first sheep to be cloned. Find out about other examples of cloned mammals.

Investigate

18. Design an experiment to investigate the effect of companion plants. You will need to begin by researching what types of plants are considered to be companion plants. While planning your investigation you should consider the following questions.
    (a) To make the test fair, what factors do you need to keep the same (control) for the plants grown with companion plants and those grown separately?
    (b) What will you observe and measure to compare the growth rates of the plants?
    (c) The effect of some companion plants is due to the smell they produce. How should this be taken into account when designing this experiment?
19. Play the **Survival game** in the Resources tab and test your knowledge on how you can help to save the environment.

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Try out this interactivity: Survival game (int-0217)

learnon

15.11 Project: Small acts, big changes

Scenario

As a member of generation Y, climate change is an issue that is very important to you. Nearly every day you hear frightening statistics about what the world will be like by 2050 unless we all make dramatic changes to our lifestyles. You are also getting frustrated by how slowly change is being initiated. Therefore, you have decided to take action yourself and create a persuasive video that will inform households and local communities of actions they can take personally to help stop the consequences of climate change.

Your task



Your task is to create a three-minute internet video to be distributed online. Your aim is for this video to become 'viral' — for it to be good enough that people want to pass it on to their friends. Your video should provide the viewer with practical advice on reducing their carbon footprint, but it should also be entertaining enough to appeal to a wide range of people who use the internet. Remember that the consequences of climate change have already begun, so your video should not only create a sense of urgency about the seriousness of the problem but also be persuasive enough to encourage its viewers to take immediate action. Therefore, you need to provide convincing and accurate facts while appealing to the emotional and intellectual capacities of your audiences.

15.12 Review

15.12.1 Study checklist

Ecosystem terms

- **define** the following terms:
  - ecosystem **15.2**
  - habitat **15.2**
  - biotic **15.2**
  - abiotic **15.2**
  - consumer **15.3**
  - producer **15.3**
  - herbivore **15.3**
  - carnivore **15.3**
  - omnivore **15.3**
  - decomposer **15.7**
  - flood **15.8**
  - drought **15.8**

Relationships in ecosystems

- **outline** examples of interactions between biotic and abiotic components of ecosystems **15.2**
- draw and **interpret** food chains and food webs **15.3**, **15.4**
- define terms relating to food chains **15.3**
- describe the relationships between organisms in a food web **15.4**

Recyclers

- **outline** some beneficial and harmful effects on micro-organisms **15.6**
- **explain** the role of decomposers in ecosystems **15.7**

Natural events

- **describe** the effects of bushfires, floods and droughts on the environment **15.8**, **15.9**
- learn about the effect of bushfires on Australian ecosystems **15.9**
- **describe** some adaptations of Australian plants to frequent bushfires **15.9**
- **describe** some technological advances that may reduce the impact of droughts, floods and cyclones **15.8**

Current issues, research and development

- **describe** the research and unique conditions in Antarctica that allow scientists to discover how conditions on Earth have changed **15.5**
- **investigate** the work of environmental scientists in Antarctica **15.5**
- **discuss** the benefits of growing plants from cuttings, runners or suckers or by other asexual means **15.10**
- **describe** some agricultural practices that have developed as our knowledge of agricultural ecosystems has improved **15.10**

Individual pathways

ACTIVITY 15.1
Investigating ecosystems
doc-10585

ACTIVITY 15.2
Analysing ecosystems
doc-10586

ACTIVITY 15.3
Investigating ecosystems further
doc-10587

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FOCUS ACTIVITY

online only

Were traditional Indigenous people the ultimate environmentalists? Create debating teams and plan your arguments.

Access more details about focus activities for this topic in the Resources tab (doc-10584).

15.12 Review 1: Looking back

assessON

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** which of the following statements are correct. Re-write any incorrect statements to make them correct.
   (a) An ecosystem is made up of only living things that interact with each other.
   (b) Temperature is a biotic factor.
   (c) Producers are animals that feed on plants.
   (d) In a food chain, the arrows show the flow of energy.
   (e) In a food web, the top-order consumers are always at the bottom.
   (f) Microbes are involved in the recycling of matter in ecosystems.
   (g) Omnivores eat plants only.
   (h) Matter flows through ecosystems and energy is recycled.
   (i) The climate is very stable in Australia.
   (j) Crop rotation can increase crop yields.

2. Redraw the table below to correctly match the heads and tails.

Heads	Tails
(a) Herbivores are …	A organisms that produce their own food.
(b) Producers are …	B animals that eat plants only.
(c) Consumers are …	C animals that eat other animals
(d) Carnivores are …	D organisms that break down dead plants and animals.
(e) Decomposers are …	E animals that eat other organisms.

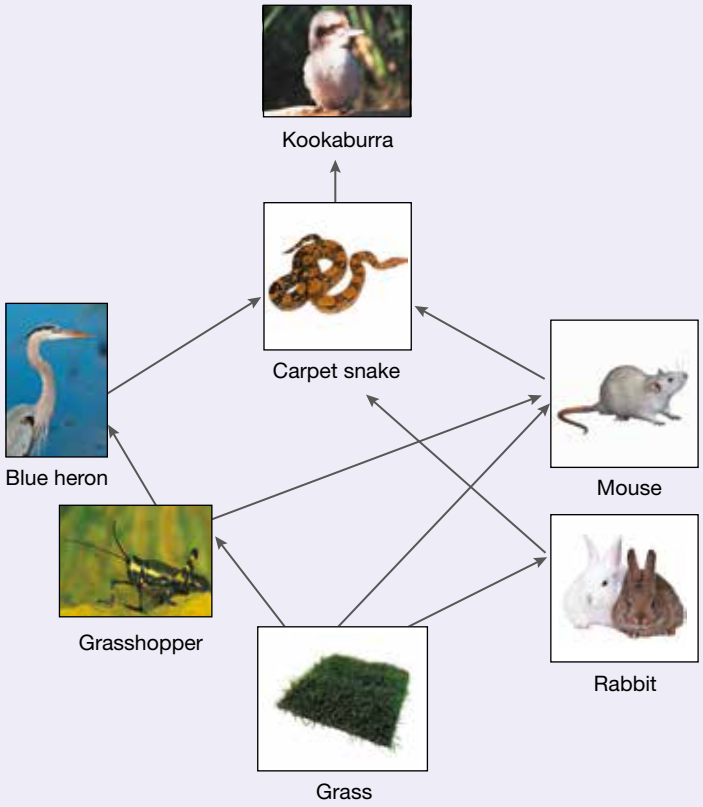
3. Copy the puzzle below into your notebook, and then use the clues to complete it.

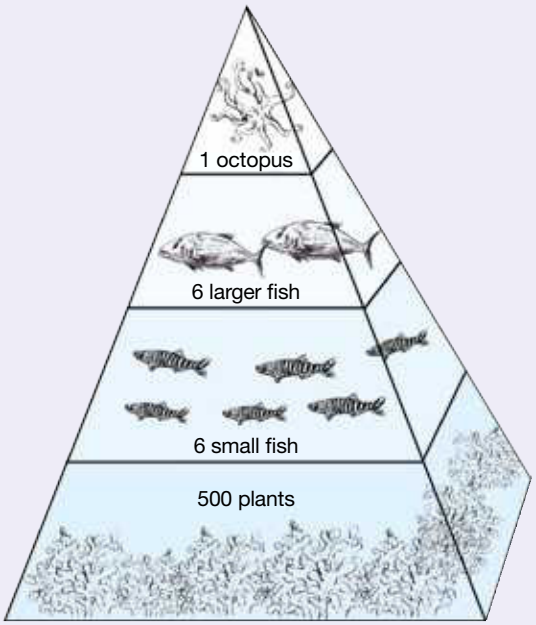
(a) __ __ __ E __ __ __
(b) __ __ N __ __ __ __ __ __ __ __
(c) __ __ __ __ __ V __ __ __ __
(d) __ __ __ I __ __ __
(e) __ __ R __ __ __ __ __ __
(f) __ __ O __ __ __ __ __ __
(g) __ __ __ N __
(h) __ __ __ __ M __ __ __ __ __ __
(i) __ __ __ __ __ E __
(j) __ __ N
(k) __ __ __ __ T __ __

Clues

(a) Caused by harmful bacteria
(b) Field that contains one main type of plants
(c) Meat-eating animals
(d) Place where an organism lives
(e) Plant-eating animal
(f) Stable system made up of living and non-living things
(g) Animal that is genetically identical to another animal
(h) Organisms such as bacteria and fungi that break down plant and animal remains
(i) Diagram that shows the feeding relationships of organisms in an ecosystem
(j) The source of all energy in ecosystems
(k) The non-living components of an ecosystem

4. Use the food web at right to answer the following questions.
   (a) **Identify** the producer and describe how it gets its food.
   (b) Draw a food chain involving a producer, a first-order consumer and a second-order consumer.
   (c) **Identify** a third-order consumer.
   (d) How do the consumers get their food?
   (e) How many trophic levels are shown?
   (f) A blue heron dies, but does not get eaten. **Explain** what would happen to its body.
   (g) **Identify** a herbivore and carnivore in the food web.
   (h) **Identify** an omnivore.
5. **Explain** why so many plants are required to support just one octopus in the ecosystem represented by the biomass pyramid shown below.





6. The powerful owl is an endangered species in Victoria. Logging has destroyed a lot of its habitat. **Explain** what would happen to the food web that the powerful owl is part of if it became extinct.
7. **Explain** why it is important for scientists to collect accurate data about the rate at which the polar icecaps are melting.
8. Sketch a diagram of the carbon cycle. Include the following terms in your diagram: respiration, photosynthesis, burning of fossil fuels, decay.
9. List three groups of decomposers. **Explain** why decomposers are essential to ecosystems.
10. **Outline** the impact of bushfires on ecosystems.
11. **Explain** why predicting natural disasters such as cyclones and floods can reduce their impact.
12. **Describe** two ways that scientific research has led to improvements in agricultural practices.

Test yourself

1. In a food web
   (A) the arrows show the direction in which energy flows.
   (B) the arrows show which species compete with each other.
   (C) the second-order consumers are always at the bottom.
   (D) the marine organisms are always at the bottom. **(1 mark)**
2. In an ecosystem
   (A) matter and energy are recycled.
   (B) only matter is recycled.
   (C) only energy is recycled.
   (D) neither matter nor energy is recycled. **(1 mark)**
3. Which of the following are examples of decomposers?
   (a) Bacteria and fungi
   (b) Bacteria and viruses
   (c) Moss and fungi
   (d) Insects and scavenger birds **(1 mark)**
4. **Classify** the following as biotic or abiotic factors.
   (a) Water
   (b) Food
   (c) Plants
   (d) Sunlight
   (e) Soil
   (f) Climate
   (g) Gases in the air
   (h) Parasites
   (i) Predators
   (j) Shelter **(2 marks)**
5. **Construct** a food web using the following information about an ecosystem.
   - Owls feed on mice and lizards.
   - Mice feed on grass seeds.
   - Small birds feed on grass, grass seeds and small insects.
   - Small insects feed on grass.
   - Cats feed on mice, small birds and lizards.
   - Lizards feed on insects. **(3 marks)**
6. **Outline** two examples of human activity that have a negative impact on natural ecosystems. **(2 marks)**
7. **Describe** one way that scientific knowledge has contributed to the development of agricultural practices. **(2 marks)**

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Complete this digital doc: Focus activity (doc-10584)

Complete this digital doc: Worksheet 15.7: Ecology puzzles (doc-12489)

Complete this digital doc: Worksheet 15.8: Ecology summary (doc-12490)

TOPIC 16
Health science

16.1 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.

16.1.1 Why learn this?

Understanding the workings of the human body and how to treat the sick has long been a human endeavour. In this chapter, you will learn about the science that led to important discoveries in the area of health and medicine, as well as some current aspects of research and development in health science and some careers in this field.

LEARNING SEQUENCE

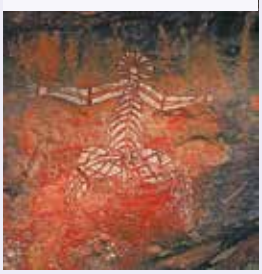
16.1	Overview	635
16.2	Looking for patterns to address health issues	637
16.3	Discovering germs	642
16.4	Germs all around us	646
16.5	A weapon against bacteria	649
16.6	A little knowledge goes a long way	653
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There are many career opportunities in the area of health and medicine.



Curiosity about the human body and health across cultures

Aboriginal 'X-ray style' rock painting figure from Kakadu National Park, Northern Territory



The quest for knowledge about the human body and how it works and about the treatment of disease is not new and it is not restricted to western cultures. Knowledge of the internal biology and physiological process in art appears in rock paintings in caves in Australia that are thousands of years old. Examples of Aboriginal X-ray art also provide evidence that this type of knowledge dates back to more than 6000 years ago.

The culture and scientific knowledge of the times often determine the types of treatment given for various diseases of the human body. In medieval times, astrology played a key role in medicine and medical prognosis. It was believed that the 'movement of the heavens' could influence human physiology, with each part of the body being associated with a different astrological sign. An image of the 'Zodiac Man' in the medical texts of the time was used to assist practitioners in their medical treatments.

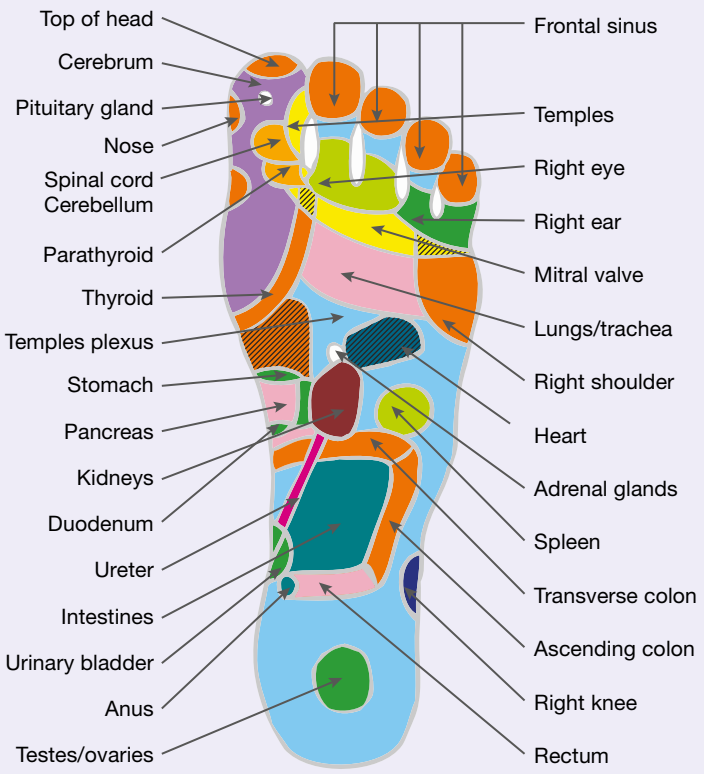
Chinese traditional medicine is an ancient medical system that has been practised for over five thousand years and applies understanding of the laws and patterns of nature to the human body. It views health as the changing flow throughout the body of vital energy (*qi*) that, if hindered, can lead to illness. Acupressure is an application of this practice that aims to release blocked energy by stimulating specific points along the body's energy channels.

1. Find other examples of X-ray paintings. What are the common features of this type of painting?
2. The Warlpiri are one of the largest Aboriginal groups in the Northern Territory. Research and report on their traditional health system and the involvement of ngangkayikirili (or ngangkari or ngangkayi) and Yawulyu ceremonies of the Warlpiri.
3. How could you test the following hypotheses scientifically?
   (a) People whose star sign is Taurus are more likely to have digestive problems than other star signs.
   (b) Colds and flus are more likely when the Leo constellation is visible in the sky at night.
4. Prepare an information leaflet about a type of therapy based on traditional Chinese medicine principles (such as Qigong, herbal therapy, acupuncture, healing foods and Chinese psychology). Your leaflet should include information about what the therapy involves, the type of conditions that are treated and any other information patients need to be aware of before beginning treatment, including possible side effects.
5. We now understand that astrology and star signs are not linked to health, but there are some diseases that are more likely to affect people born at a particular time of the year. It has nothing to do with star signs though! Use the **Star sign health** weblink in your Resources tab and summarise the key points made in the article.

The 'Zodiac Man' chart was based on astrology and provided advice on when, for example, to 'bloodlet' (a medical treatment involving bleeding the patient), regulated by the position of the moon.



An example of an acupressure reflexology chart



16.2 Looking for patterns to address health issues

16.2.1 Asthma — on the rise?

Why do so many Australian children suffer from asthma? How does smoking cause lung cancer? Should babies be placed on their back or tummy in their cots to reduce the incidence of cot death? To find answers to questions such as these, scientists sometimes turn to statistics. Looking for patterns in large amounts of data can provide answers to important questions.

Even if you do not suffer from **asthma**, it is very likely that you know someone who does. Asthma is a very common condition that affects about one in seven Australian adolescents. About one in ten, or 10 per cent, of adults are affected. Young children are the greatest sufferers of asthma, with one in four affected. One alarming fact about asthma is that the number of people who suffer from it has greatly increased in the last 30 years. The reasons for this increase are not clear but you might have some ideas of your own after reading this information.

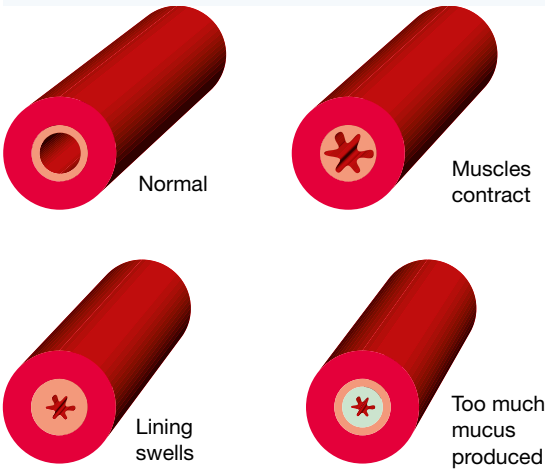
What is asthma?

Asthma is a narrowing of the air pipes that join the mouth and nose to the lungs. The pipes most affected are the bronchi. They become narrower as:

- the muscle wall of the air pipes contracts
- the lining of the air pipes swells
- too much mucus is produced.

The narrow pipes make breathing difficult and can result in wheezing, coughing and a tight feeling in the chest. The coughing is usually worse at night.

Asthma is a narrowing of the air pipes.



Triggers

Some of the common triggers of an asthma attack are:

- vigorous exercise
- cold weather
- cigarette smoke
- dust and dust mites
- moulds
- pollen
- air pollution
- some foods and food additives
- some animals.

Not all asthma sufferers are affected by the same triggers. Some people suffer attacks only as a result of exercise. Others might be affected by any one or more of the triggers. It is important that those who get asthma try to find out what triggers the attacks. Many of the triggers can be avoided.

The best way to control asthma is to try to avoid the triggers as far as possible.

16.2.2 What causes asthma?

The exact reason why some people suffer from asthma and others do not is not known, but there appear to be a number of contributing factors. One way to find out about the causes of asthma is to look for patterns in data. Data about asthma have revealed the following trends:

- Children who have a parent with asthma, eczema or hay fever are more likely to develop asthma. This suggests that heredity plays a part in asthma.
- Being overweight increases the risk of asthma.

- Children whose parents smoke are more likely to have respiratory infections in infancy and, in turn, develop asthma.
- People who are exposed to certain chemicals through their work are at higher risk of developing asthma.

Some researchers are particularly concerned about the increase in the incidence of asthma over recent times. A number of hypotheses have been put forward, but perhaps the most interesting one is the hygiene hypothesis (see page 639).

16.2.3 What is lung cancer?

It seems hard to believe but there was a time when people did not know that smoking causes lung cancer. Over time it became obvious that people who developed lung cancer tended to be smokers. Now we know that there is a clear link between smoking and lung cancer, as well as other diseases including other types of cancer and cardiovascular diseases.

A lung X-ray can be used to detect lung cancer.

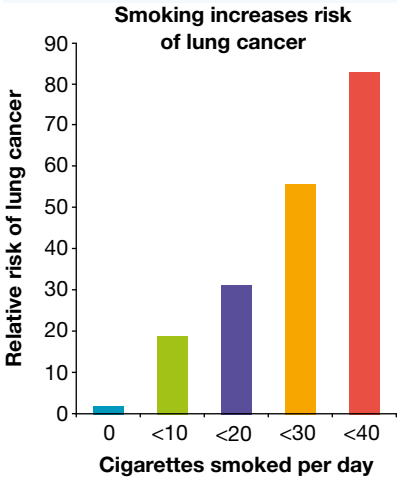


Lung cancer starts as a lump of cells multiplying out of control in the lungs. Unlike normal lung cells, cancer cells are not specialised, so they cannot do the job of healthy lung cells. This interferes with the normal functioning of the lungs. As the cancer grows, the mass of cells can block some of the bronchioles, causing breathing problems. The cancer can also spread to other organs and cause further problems. Unfortunately, lung cancer has the highest death rate of any cancer.

The link between smoking and lung cancer

A number of studies have shown that there is a clear link between smoking and the likelihood of developing lung cancer. The two graphs at right show the results of two of these studies. Can you make sense of these graphs?

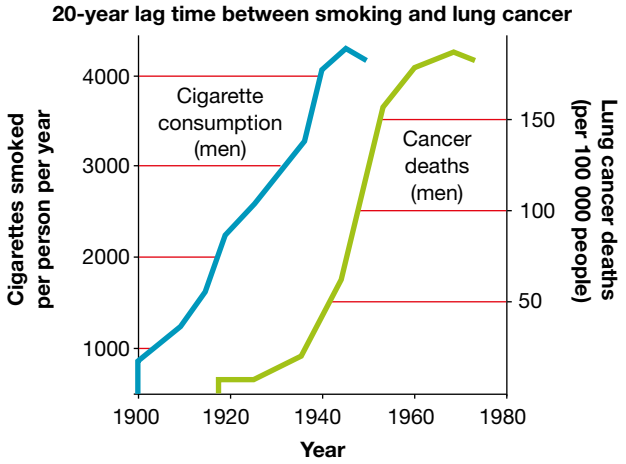
Graph 1: The risk of dying from lung cancer increases with the number of cigarettes smoked daily.



16.2.4 SIDS — can we reduce the risk?

Each year, apparently healthy babies die from sudden infant death syndrome (SIDS). The exact cause of SIDS is not known, and it is likely that a number of factors are involved. The good news is that the rate of death from SIDS has been decreasing, due to advice that has been given to new parents about minimising the risk. To work out the best advice to give parents, researchers collected data about babies, including information about the type of bedding, whether the babies were placed in their cots on their tummy, back or side and whether their parents smoked. The incidence of SIDS is lower in babies who sleep on their back rather than their tummy, and in their own cot rather than sharing a bed with a parent or sibling. Avoiding bulky doonas, pillows and soft toys in the baby's cot also reduces the risk of SIDS whereas having parents who smoke increases the risk.

Graph 2: This graph shows that the number of deaths from lung cancer has risen as cigarette consumption has increased, but there is a 20-year lag time because lung cancer takes many years to develop.



The incidence of SIDS is lower in babies who sleep on their back.



The hygiene hypothesis

According to this hypothesis, diseases such as asthma, eczema, hay fever and some other allergies might be increasing because children are being brought up in an environment that is too clean. If children are not exposed to enough germs as children, their immune system (the system that fights off germs that invade the body) does not develop properly. The result is that sometimes the immune system will mistake harmless substances (such as pollen) for nasty germs and go into full attack mode when exposed to these. The result is an asthma attack or an allergic reaction.

The following data have been used to support this hypothesis.

- Children who grow up on farms (where there are a lot more germs) are less likely to get asthma than children who grow up in cities. The more children are exposed to the faeces (poo) of animals, the less likely they are to get asthma.
- Young children who live in a house where there is a pet (a source of germs) are less likely to develop asthma.
- Children who go to day care or have older brothers and sisters are less likely to get asthma than children who are not exposed to the germs of other children.

At present, the 'hygiene hypothesis' is just that — a hypothesis. That means scientists are not sure whether it is correct or not. Further scientific studies may either support or disagree with this hypothesis. For now, many doctors are advising parents that a bit of dirt is not such a bad thing for toddlers.

Professor Robyn E. O'Hehir
BSc, MBBS (Hons I), FRACP, PhD, FRCP, FRCPath

1. What is your current science-related title?
I am a Professor of Medicine, with particular responsibilities for allergy, clinical immunology and respiratory medicine, at Monash University, Melbourne. I am also the Director of the Department of Allergy, Immunology and Respiratory Medicine at the Alfred Hospital in Melbourne.

2. What field of science are you in?
Allergy, cellular immunology and respiratory medicine. I was appointed to the first Chair in Allergy and Clinical Immunology in Australia.

3. Describe some science that you are involved in at the moment.
Millions of people around the world suffer from allergies. I am sure you know several friends who have asthma or hay fever, or you may even have them yourself. Asthma and hay fever are usually triggered by proteins called allergens, from house dust mites or grass pollens. Allergies to peanuts and shellfish are less common but often more serious, because they can trigger life-threatening allergic reactions called anaphylaxis. Allergies are caused by reactions between white blood cells ('T cells') and environmental proteins that are usually harmless. My research group is trying to find ways to damp down the allergic T-cell responses.

Allergen immunotherapy (allergy shots) is the only treatment that can prevent allergic diseases, but currently it can't be used for peanut, even though this is one of the most serious allergens. To develop a safe and effective vaccine against peanut allergies, we are identifying parts of critical peanut proteins that can build up tolerance in allergic patients without risking anaphylaxis.

4. What do you enjoy about being a scientist?
I enjoy the fact that my research not only is laboratory based, exploring novel methods for switching off allergic responses, but also lets me see patients and train other doctors in how to do research from bench to bedside to the community. I head an active clinical department, still carry out clinics with patients, and am actively engaged in national and international tests of new preventions and treatments for allergies. My combined research and clinical duties allow us to put our research findings into better clinical practice.

5. What triggered your interest in science?
I decided to specialise in allergy and respiratory medicine, focusing on asthma, following my experiences as a young trainee physician at the Alfred Hospital in Melbourne. Asthma was a huge problem in Australia at that time, and many times I resuscitated young adults in the hospital emergency room — and I watched them return, with appropriate medication and careful education, to confident, full lives. Some remain my patients today. The ability to dissect underlying mechanisms of disease and then work towards new therapies and practices to benefit patients is a great excitement and honour. The diversity of patients and their needs ensures that every day is quite different.

Professor Robyn O'Hehir



6. Do you have any other comments that may be of interest to Science students?
Training for a career in science combined with medicine may take a bit longer, but it gives you a fantastic ability to do interesting work that is intellectually demanding and also involves working with lots of people who need your help. I am very glad that I chose a career in science and medicine.

16.2 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. **Describe** what happens to the air pipes in the lungs during an asthma attack to make breathing difficult.
2. **Explain** why an asthma attack is more likely to be triggered in a person with a cold.
3. **Define** the term 'asthma trigger'.
4. **Recall** what SIDS stands for.
5. **Define** the terms 'allergen' and 'anaphylaxis'.
6. How is Professor O'Hehir contributing to finding a cure for life-threatening peanut allergies?

Think and discuss

7. If you were part of an audience of 1400 students in a concert hall for a music excursion, **calculate** how many of them would be likely to be asthma sufferers. (*Hint:* Use the information on page 637.)
8. The number of people who suffer from asthma has doubled in the last 30 years. The hygiene hypothesis is just one possible explanation for this.
   (a) **Outline** some other possible reasons why the number of people suffering from asthma has increased so dramatically.
   (b) Write down two hypotheses suggesting why there has been a sharp increase in the incidence of asthma.
   (c) **Outline** how each of your hypotheses could be tested.
9. (a) In a group, brainstorm ideas about the common triggers of asthma and how they can be controlled.
   (b) **Summarise** your discussion in a table similar to the one below.

Trigger	How the trigger can be controlled
Moulds	Air the house regularly.

10. Design an investigation based on statistical evidence to test the following hypothesis: 'Babies who sleep on their back have a reduced risk of cot death'. (*Note:* Your investigation must be ethical.)

Skill Builder

11. The table below shows how the rate of smoking has changed over the past 60 years or so.

Percentage of adult Australians who smoke

Year	1945	1964	1969	1974	1976	1980	1983	1986	1989	1992	1998	2004
Males (%)	72	58	45	41	40	40	37	33	30	28	29	26
Females (%)	26	28	28	29	31	31	30	28	27	24	24	20

   (a) **Construct** a line graph for the data in the table. Use 'Year' on the *x*-axis and '% of adult Australians who smoke' on the *y*-axis. Draw lines for males and females in different colours.
   (b) Suggest why the percentage of females who smoke has changed little while the percentage of males who smoke has declined greatly.
   (c) Use dotted lines to **predict** the trends up to the year 2020. What percentage of males and females do you predict will be smoking in the year 2020?
12. Study graph 1 on page 638.
   (a) Copy and complete the following statements:
      (i) People who smoke 10 cigarettes a day are_____ times more likely to develop lung cancer than non-smokers.
      (ii) People who smoke 30 cigarettes a day are_____ times more likely to develop lung cancer than people who smoke 10 cigarettes a day.
   (b) If a packet of cigarettes costs $15 and contains 20 cigarettes, **calculate** how much a person smoking 40 cigarettes a day spends on smoking:
      (i) each day
      (ii) each week
      (iii) each year.
13. Study graph 2 on page 639.
   (a) **Describe** how the number of deaths from lung cancer changed between 1900 and 1980.
   (b) **Identify** when the number of male smokers peaked.
   (c) **Identify** when the number of deaths from lung cancer peaked.
   (d) **Explain** why there is a 20-year gap between the two numbers.
   (e) The graph shows data for male smokers only. **Predict** when the number of cases of lung cancer in women peaked (use the graph you drew for question 12 to answer this).

Discuss

14. Smoking-related diseases cost taxpayers many millions of dollars because hospitals are mostly paid for by governments. Write down your opinion of each of the proposals below. **Justify** your opinion.
   (a) The cost of hospital treatment for diseases caused by smoking should be paid by the patient because it was their fault that they got sick.

(b) Cigarettes should cost more. The extra money made from them could then be given to hospitals to help pay for treating people with smoking-related diseases.
(c) Cigarette companies who make profits from smoking should be made to pay for hospital treatment of patients with diseases caused by smoking.

15. Although smoking is now banned in many places, including public transport vehicles, workplaces and some restaurants, it is still legal. **Propose** why smoking has not been made illegal when it causes so much damage?
16. In 2013 Australia was the first country in the world to introduce plain packaging of cigarettes. Cigarettes must now be sold in a plain dull green package and display graphic images depicting the health effects of smoking. Tobacco companies cannot use their logo, special lettering or colours other than dull green on the cigarette packages.
    (a) Tobacco companies were opposed to the introduction of plain packaging for cigarettes. Suggest why.
    (b) If you were a researcher in charge of testing the impact of the introduction of plain packaging on smoking rate, what type of data would you need to collect?
    (c) When plain packaging was first introduced some smokers reported that the taste of the cigarettes had changed. Design an experiment involving smokers to test whether the type of packaging affects the perceived taste of cigarettes.
17. Use the **Quit Now** weblink in the Resources tab to learn about the national tobacco campaign. Create a poster that sends one single important message about smoking.
18. Use the **Red Nose Day** weblink in the Resources tab to find out what this day is about.

learnon RESOURCES — ONLINE ONLY

Complete this digital doc: Worksheet 16.1: Smoking and diseases (doc-12491)

Explore this web link for terms: Quit Now

Explore this web link for terms: Red Nose Day

16.3 Discovering germs

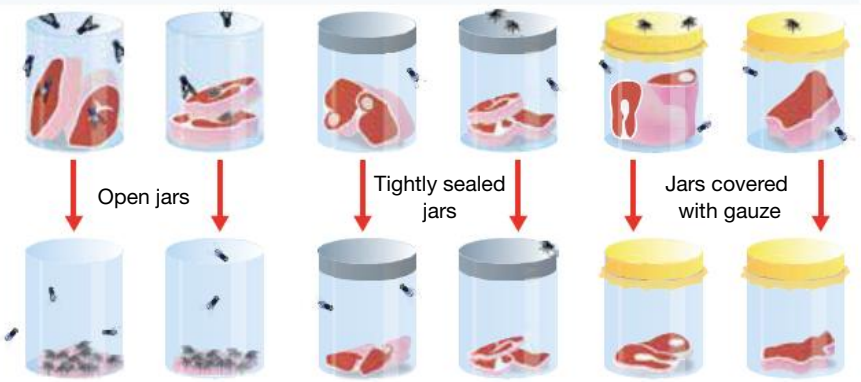
16.3.1 Dispelling the myth of spontaneous generation

Today, a surgeon would not dream of performing an operation without first washing their hands thoroughly and donning gloves and medical scrubs. Waste from toilets is now collected in pipes and no longer runs down city streets, and strict health regulations apply to the preparation and storage of food in supermarkets and restaurants. This was not always the case. Over time, increasing knowledge about microbes and the causes of disease has led to changes in hygiene practices and the way we store food and deal with waste.

Until the nineteenth century, it was generally accepted that life could arise spontaneously. It was thought possible for living organisms to arise out of non-living matter. It had been noticed that maggots could appear on meat and that mice could emerge from a pile of old rags. Microbes seemed to simply appear on rotting food.

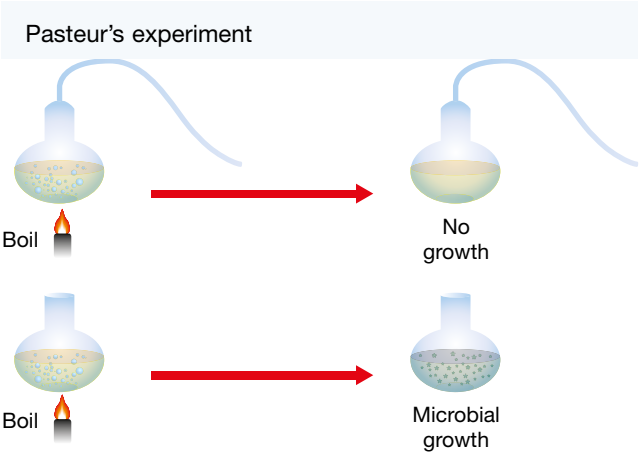
In 1668 Francesco Redi carried out a simple experiment to show that maggots do not form spontaneously on rotting meat; they form only when flies are able to lay eggs on the meat. He placed meat in jars. Some of the jars were left open, some were sealed and some had fine gauze covering the opening of the jar. Maggots appeared on

Redi's experiment



the meat that had been left in the open jars, but not in the sealed jars or the jars where gauze prevented flies from laying eggs on the meat.

An experiment set up by Louis Pasteur in 1859 finally dispelled the myth of spontaneous generation. Pasteur heated some broth in flasks. He then heated the neck of the flask and bent it into the shape of a swan's neck. The shape of the neck of the flask meant that the flask was not sealed from the outside air but microbes could not fall from the air into the broth; they would get stuck in the lowest part of the flask's curved neck. As predicted by Pasteur, the broth remained clear, with no evidence of microbial growth. If he broke the neck of the flask or tipped it sideways so that the broth reached the lower part of the curved neck (where microbes would be expected to settle), the broth rapidly spoiled.



Pasteur's experiment showed that food can be prevented from spoiling by firstly using heat to kill any microbes growing in or on the food, and then ensuring that germs are not able to settle on the food. This is the principle behind preserving food. The food is placed in metal or glass containers and heated to high temperatures. Provided the container is not damaged or unsealed, the food inside will not decay.

INVESTIGATION 16.1

Pasteur's experiment

AIM: To demonstrate Pasteur's experiment



You will need:

broth
2 conical flasks
2 corks with a piece of glass tubing inserted in each; one of the tubes should be straight and the other bent, as in the photo at right

- Quarter-fill each flask with broth.
- Using a Bunsen burner or microwave oven, heat the flasks until the broth has boiled. Then leave them on low heat for a further minute. (If using a microwave oven, heat the broth for short bursts of time after boiling rather than for a continuous 60 seconds.)
- Insert one of the corks with glass tubing into each flask. Ensure that the broth is still very hot when you do this so that the steam from the broth can pass through the glass tubing to sterilise it.
- Leave the flasks undisturbed for at least 2 weeks. Inspect the flasks each lesson for signs of microbial growth. Record your results in a table.

Discussion

1. Could air enter or leave the flasks? Explain your answer.
2. Could microbes enter the flasks? Explain your answer.
3. Which flask is the control?
4. Write a conclusion for this experiment.

16.3.2 Improving hygiene in hospitals

Sir Joseph Lister was a surgeon in the nineteenth century. When he began his surgical career it was not common practice for surgeons to wash their hands between patients or even wear clean clothes for surgery. A smelly apron with stains of dried blood was considered a status symbol. Lister read some of Pasteur's research about microbes and became interested in ways of eliminating the germs that cause gangrene.

Gangrene was a common problem following surgery. The area around the incision became infected and the tissue around the infection died and turned black. To stop the infection from spreading and killing the patient, it was often necessary to amputate the part of the body where gangrene had set in. Lister tested the

effectiveness of spraying a solution of carbolic acid on surgical instruments, surgical incisions and dressings. He found that this greatly reduced the incidence of gangrene. Further work led him to publish a paper in which he described some techniques to reduce the risk of infection during surgery. These techniques included wearing clean gloves and using carbolic acid to clean surgical instruments and the hands of the surgeon.

Florence Nightingale also played an important role in improving hygiene standards in hospitals. She was a British nurse who spent some time working in a military hospital during the Crimean War where she observed the high rate of infections and deaths in unsanitary conditions. On her return to Britain she started collecting data about hygiene practices and patient outcomes. In the second half of the nineteenth century she set up a training school and wrote a training guide for nurses in which she outlined some of the sanitary practices that are still used in hospitals today.

16.3.3 Finding patterns in cholera outbreaks led to improved sanitation

In 1854 there was an outbreak of cholera in London. To identify the cause of the outbreak, John Snow, a doctor, had earlier hypothesised that cholera was spread by drinking water or eating food contaminated

What can you infer from this map? What could be causing the cholera outbreak?



with sewage. At the time, most people thought cholera was transmitted through the air. Snow plotted the location of deaths due to cholera on a map, similar to that shown on the previous page. A large number of the cholera cases were clustered around a particular water well. The handle of the well was removed so it could no longer be used and the epidemic soon ended. This confirmed that the water from the well must have been making people sick.

In 1883 Robert Koch, a German doctor, identified the cause of cholera: the bacterium *Vibrio cholera*. He discovered that the bacterium was transmitted when drinking water or food was contaminated with the faeces of an infected person. The work of Snow and Koch showed the importance of adequate sewage treatment.

16.3 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. **Outline** the theory of spontaneous generation. Is it still accepted today?
2. Draw a sketch of Pasteur's swan-neck flask. Show where microbes falling in from the air might accumulate.
3. **Explain** why canned food does not decay unless the tin is damaged or has been opened.
4. Why was gangrene a common problem following surgery in the nineteenth century?
5. **Outline** Lister's contribution to modern medicine.
6. What is the cause of cholera?
7. How is cholera transmitted?

Think

8. Study the diagram of Redi's experiment on page 642.
   (a) Which were the control flasks?
   (b) Why did Redi have jars covered with gauze in addition to the open and sealed jars?
   (c) Could the same experiment be used to show that bacteria cannot generate spontaneously? **Explain** your answer.
9. When health professionals give an injection, they first swipe the skin with alcohol or another antiseptic solution.
   (a) What is the purpose of swiping the skin with alcohol?
   (b) How could the effectiveness of this procedure be assessed? (*Hint:* Animals other than humans could be used to test the procedure.)
10. Florence Nightingale collected and recorded a great deal of data about hygiene conditions in hospitals and patient outcomes. Why was this important?
11. Examine the map on page 644.
   (a) On which street was the pump that was the suspected source of the cholera outbreak.
   (b) If cholera had been spread via the air, would the deaths from cholera have shown the same distribution? **Explain** your answer.

Investigate

12. Canning is one way of preserving food. Other techniques used to preserve food include freezing, salting, pickling and freeze drying. Find out what each technique involves and how it works.
13. Find out what pasteurisation involves.
14. John Snow's plotting of cholera cases on a map was an early example of epidemiology. Find out the meaning of the term 'epidemiology'.

16.4 Germs all around us

16.4.1 Bacterial shapes

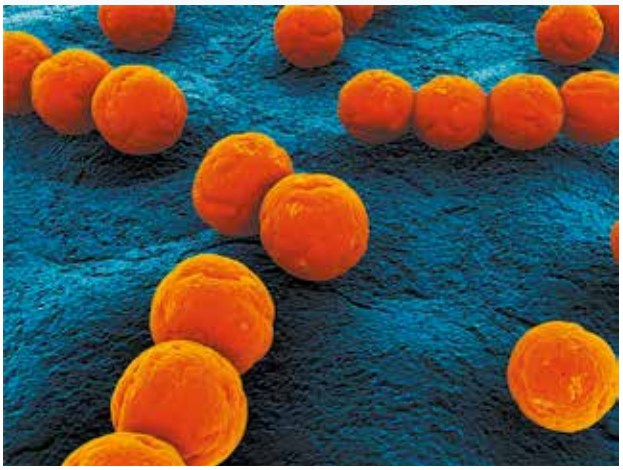
The number of bacterial cells living in and on your body is about ten times as high as the number of human cells that make up your body. Bacteria live on your skin, in your ears, nose and mouth, and in your intestine. Bacteria are also found in soil, in oceans and rivers, on the food we eat and on the objects we touch.

Bacteria come in different shapes and their names often indicate their shapes and how they clump together. Some bacteria are round (coccus) and some are rod shaped (bacillus). Some are spiral shaped (spirillum) and some are comma shaped (vibrio). The prefix strepto- is used to describe bacteria that form chains. *Streptococcus* consists of round cells that organise themselves in chains, whereas *Streptobacillus* are rod-shaped cells arranged in a chain. When bacteria are organised in pairs, the prefix diplo- is used. *Diplococcus* consists of two round cells inside a capsule. The prefix staphylo- indicates bacteria that clump together like a bunch of grapes.

Vibrio bacteria



Streptococcus bacteria



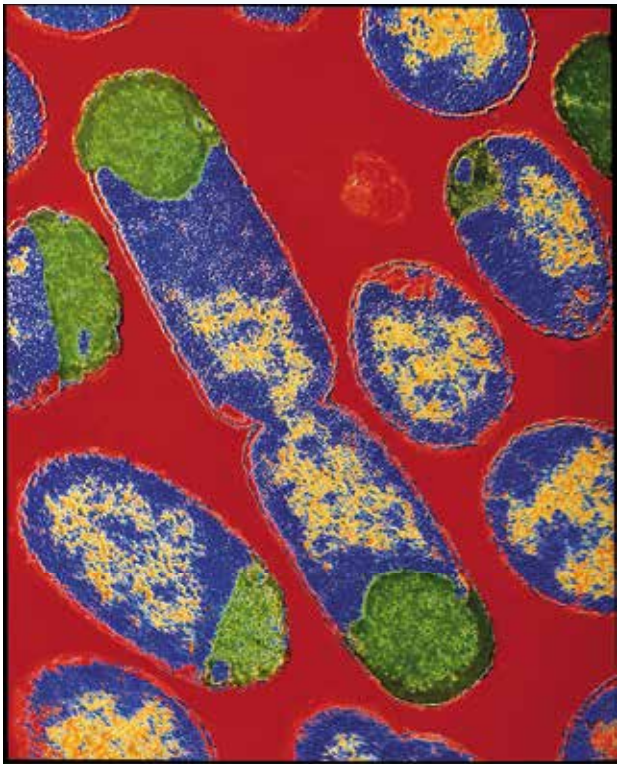
16.4.2 From one to many

Bacteria reproduce by **binary fission**; a single cell divides into two cells. These two cells then grow until they reach a certain size. Each of them then divides into two to produce four cells. These four cells in turn divide to produce eight cells. If the bacteria are in ideal conditions, this process can occur quite rapidly. In fact, if a single bacterium is kept in a moist environment, provided with a supply of nutrients and kept at the right temperature, it can give rise to a colony of bacteria that is so large it can be seen without a microscope in just 24 hours.

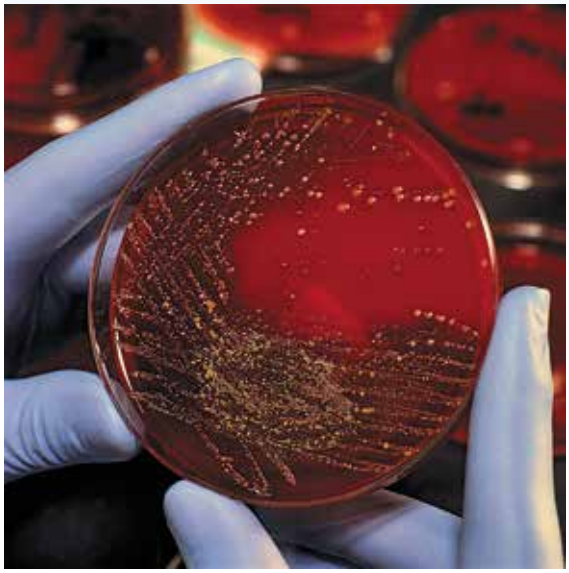
Microbiologists are scientists who study microbes. They can find out a lot about bacteria by growing them on agar, which is a jelly-like substance. (Some people eat agar as a dessert.) The agar is poured into a shallow dish called a **Petri dish** and allowed to set. Substances such as vegemite can be added to the agar to help bacteria grow. When microbiologists grow bacteria that live in blood, they use blood agar, which is a mixture of blood and agar that sets like jelly.

To grow colonies of bacteria, a very small amount is wiped onto the surface of the agar; at this stage, they cannot be seen. The agar plate is then **incubated**; that is, it is left in a cabinet that maintains the optimum temperature for bacterial growth. The bacteria divide over and over by binary fission. After one or two days, the agar plates are removed from the incubator. Colonies of bacteria can be seen on the agar. Colonies contain thousands of bacteria. Each colony is formed from one bacterium by binary fission.

Bacteria reproduce by binary fission.



Colonies of bacteria on an agar plate



INVESTIGATION 16.2

Where are those germs?

AIM: To examine the types of microbes found in various places

You will need:

sterile cotton buds
nutrient agar plates in Petri dishes (3 per group)
sticky tape
marker pen
sterile Pasteur pipette

CAUTION: Agar plates should not be opened after incubation.

- Seal the spare plate (only one is needed for the whole class). Label this plate 'control'. Incubate it with the other plates.
- Swipe a sterile cotton bud across a surface of your choice (such as canteen counter, computer keyboard, phone mouthpiece or bin lid).
- Swipe the cotton bud across the surface of the agar. Be careful not to push down too hard. The cotton bud should not leave a mark on the agar.
- Use sticky tape to seal the plate around the edge.
- Use a marker pen to write your group's name and where you collected the sample from.
- Use a different cotton bud to swipe a part of your body (such as the inside of your nose, your teeth, inside your ear or your scalp).
- Swipe the cotton bud on the surface of the second agar plate, then seal and label it as before.
- Use the sterile Pasteur pipette to collect about 1 mL water from a location of your choice (such as a fish tank, puddle, local creek, school swimming pool or drain pipe).
- Drip the sample of water over the surface of the agar and swish it around. Seal and label the agar as before.
- Incubate the three plates upside down at 30 °C for 48 hours. Remove the plates from the incubator and observe the colonies of bacteria through the lid of the Petri dishes (do not open the Petri dishes).

Discussion

1. Describe five of the colonies of microbes on each plate. Include information about the colour and size of the colonies, whether the colony has a smooth or rough edge, whether it is flat, raised or furry and whether it has a dull or glossy appearance. Remember to look at the microbes through the plastic lid. Do not open the plates.
2. Colonies of bacteria tend to be smooth whereas colonies of fungi appear furry and are often larger. Do you have colonies of bacteria or fungi or both on your plates?
3. Look at the other groups' plates.
   (a) Which of the surfaces tested by your class had the most microbes? How can you tell?
   (b) Which body part tested had the most microbes?
   (c) Which of the water samples tested contained the most microbes?
4. Explain why it would be dangerous to unseal the agar plates and lift the lid to look at the colonies of microbes.
5. Explain why a control plate was needed.
6. Find out from your teacher how the plates are disposed of safely at your school.
7. Design an experiment to test whether antibacterial surface spray really does kill bacteria.

HOW ABOUT THAT!

It is possible to grow bacteria on gelatine (the substance that makes jelly set). Gelatine is not as suitable as agar though because it melts in hot weather and some bacteria can digest gelatine and turn it into liquid. These are the problems that the microbiologist Walther Hesse faced until he asked his wife how she managed to make jellies that did not melt in hot weather. Lina Hesse's secret recipe was agar. She had got the idea of using agar in her jellies from a neighbour who had emigrated from Java. Walther Hesse switched from using gelatine to agar with great success. This technique was then adopted by Robert Koch, a famous microbiologist Hesse was working with, and today agar is one of the most common substances used to grow bacteria.

16.4 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. List some places where bacteria are found.
2. Match each word part on the left with one of the descriptions on the right.

Word part	Description
(a) Coccus	A Comma shaped
(b) Strepto	B Spiral shaped
(c) Staphylo	C Chain of bacterial cells
(d) Spirillum	D Round
(e) Diplo	E Bacterial cells organised in a clump like grapes
(f) Vibrio	F Rod shaped
(g) Bacillus	G Two bacterial cells enclosed by a capsule

3. **Outline** how bacteria reproduce.
4. **Recall** what bacteria need to grow and reproduce.
5. What is agar? **Explain** why it is an ideal substance to grow bacteria on.

Think and analyse

6. Draw a diagram of *Streptobacillus*.
7. The number of bacteria living on and in your body is about 10 times the number of human cells that make up your body, yet bacteria make up only about one to two per cent of your body's dry mass. Suggest why.

8. *Escherichia coli* is a species of bacteria. Under ideal conditions, the generation time for *E. coli* is 40 minutes. That means that every 40 minutes the *E. coli* cells divide to produce two cells.
   (a) Copy and complete the table below.

Generation	Time (min)	Number of cells
1	0	1
2	40	2
3	80	4
4	120	8
5	160	
6	200	
7		
8		
9		
10		

   (b) **Construct** a graph showing how the number of cells changes over time. Time should be on the horizontal axis and the number of cells on the vertical axis.
   (c) **Describe** the shape of the graph.
   (d) **Deduce** how long it would take for a colony of *E. coli* to reach over 2000 cells.
9. When microbiologists prepare agar to grow bacteria, they boil the agar mixture for a few minutes to ensure that the agar is sterile (free of microbes). **Explain** why it is important for the agar to be sterile.
10. The Petri dish was named after Julius Richard Petri, the person who invented it. He was an assistant for Robert Koch and he found that a shallow dish with a lid that was slightly bigger than the base was ideal to grow microbes.
    (a) Why does a shallow dish work better than a beaker to grow bacteria on agar?
    (b) Why do Petri dishes need a lid?
    (c) The lid of a Petri dish can be sealed with sticky tape but, when unsealed, it is easy to lift with one hand. Why is this an important feature of Petri dishes?

Investigate

11. Your Science teacher regularly tells the class not to leave wet cleaning cloths in the sink. Instead cloths should be wrung and allowed to dry. Design an experiment to test whether there are more germs on a cloth that has been left in the sink overnight or on a cloth that was rinsed, wrung and allowed to dry.
12. Robert Koch made some important contributions to microbiology. Write a report about some of the discoveries made by Koch.

learnON RESOURCES — ONLINE ONLY

Watch this eLesson: Mystery of the flesh eaters (eles-1082)

Complete this digital doc: Worksheet 16.2: Classifying bacteria (doc-12492)

16.5 A weapon against bacteria

Science as a human endeavour

16.5.1 An accidental discovery

One hundred years ago, many children died both from infectious diseases and bacterial infections. A small scratch was sometimes enough to allow deadly bacteria to enter the body and cause swelling, the formation of pus and severe pain. Children born today can avoid the harsh consequences of many bacterial infections.

The first antibiotic to be used successfully to treat a patient was penicillin. Alexander Fleming discovered the antibacterial properties of penicillin by accident. He had been growing bacteria on agar plates, and when he went on holidays he forgot that he had left some open agar plates on a bench near a window

sill. When Fleming came back from his holiday, he noticed that mould was growing on some of the plates. No bacteria had grown around the mould but the rest of the plates were covered with bacteria. He concluded that the mould must be producing a substance that prevents the growth of bacteria. He called the substance penicillin, but he was not able to extract it, so it could not yet be used to treat bacterial infections.

Today, we take antibiotics to avoid the harsh consequences of bacterial infections. These photographs of a young patient in 1942 show how serious an infection can be. After being treated with penicillin, the patient's condition improved and she recovered fully.



The Australian connection

It was a team of scientists, led by an Australian named Howard Florey, that discovered how to extract penicillin. Howard Florey was born in Adelaide in South Australia in 1898. He was a keen student who loved sport and chemistry. He studied medicine at the University of Adelaide where he won a Rhodes scholarship to Oxford University, England. While in England he led the team that finally extracted **penicillin** in 1940. In 1945 he shared his Nobel prize with Alexander Fleming and Ernst Chain. In speaking of his discovery, he modestly stated, 'All we did was to do some experiments and have the luck to hit on a substance with astonishing properties'.

Penicillin was so successful in saving lives that population control became an issue for medical researchers. Florey later worked on contraception research. In honour of his contribution to medicine, he was knighted in 1944. His likeness appeared on an Australian $50 banknote and a suburb of Canberra was named after him.

Howard Florey



16.5.2 Scientists working in teams

In the 1940s, it was unusual for scientists to work in teams. Yet Howard Florey gathered together a group of experts and divided the problem up so each one worked in an area that best suited their talents. The researchers and their responsibilities were as follows:

- Ernst Chain shared the Nobel prize for the discovery of penicillin. Chain found Fleming's notes and brought them to the attention of the team. He worked with Edward Abrahams looking for ways to purify penicillin.
- Norman Heatley used ether and bedpans to develop ways to extract penicillin.
- AD Gardner and Jena Orr-Ewing worked together to see how organisms reacted to penicillin.
- Margaret Jennings worked with Florey to conduct animal trials with the substance. Their most important test was conducted on Saturday 24 May 1940. They gave eight mice a lethal dose of streptococcus bacteria. They then gave four mice penicillin. Within 24 hours these four had recovered while the four control mice were dead. They knew they had something worth telling the world about.
- Ethel Florey worked with her husband on the clinical trials of penicillin.

Albert Alexander was the first human to be treated with penicillin. He had been scratched by a rose thorn, and his face was so terribly swollen with a bacterial infection that his only remaining eye had to be lanced. He was given penicillin and started to recover, but unfortunately not enough penicillin was available to control his horrendous infection and he died. Florey's team then worked hard to make large quantities of penicillin. The war in Europe meant there was little financial support for their work. However, Fleming went to America and got assistance to begin mass production of the drug, and it was used to treat wounded soldiers in the last months of World War II.

Miracle cure-all?

Initially penicillin had to be injected in the bloodstream, as natural penicillin is destroyed by stomach acid. Today, it is possible to treat many infections by taking syrup or tablets containing chemicals derived from penicillin. These chemicals are not broken down by stomach acid. Once the penicillin reaches the bloodstream, it works by stopping bacteria from forming cell walls as they try to divide. This is why penicillin is useful for treating bacterial infections only; it is powerless against viruses. A case of the flu or chickenpox, both viral infections, cannot be cured with antibiotics.

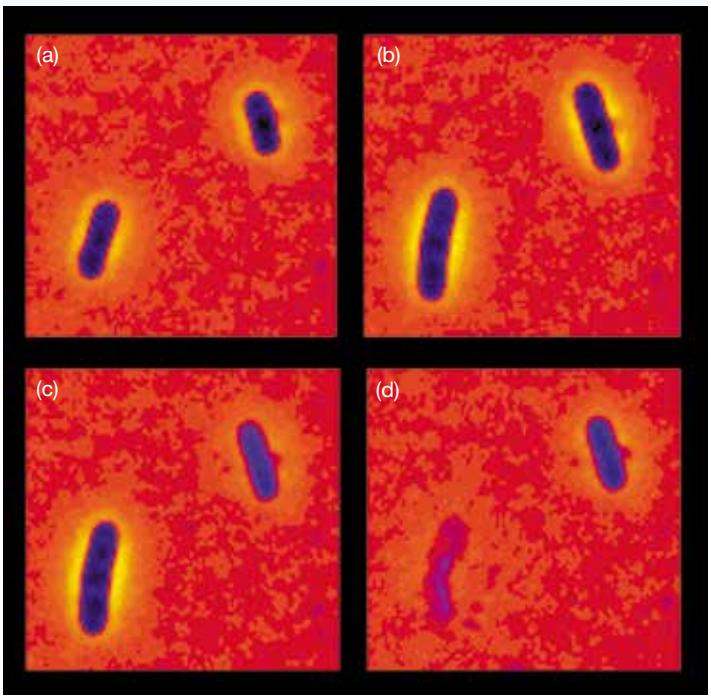
16.5.3 Are antibiotics overused?

Penicillin and other antibiotics have some drawbacks including allergic reactions. Also, there is concern that they are being overused. A small percentage of the population is allergic to penicillin. If you develop any signs of allergy while taking antibiotics, it is important to go back to the doctor as you may need to change to a different type of medication. Another problem is antibiotic resistance. When penicillin was first discovered it was effective against a large number of bacteria. Increasingly there are instances where a patient may show no improvement after taking penicillin to treat a bacterial infection, or they might show some improvement initially and then relapse rather than continue to improve. The bacteria making them sick may be resistant to penicillin.

Bacteria reproduce quickly, so they can evolve rapidly. Each time a new antibiotic is discovered and used to treat disease it acts as a selecting agent. Over time, the proportion of bacteria that are resistant to that particular antibiotic increases. A drug called vancomycin is currently reserved for cases where other antibiotics have failed. It is used to treat so called 'superbugs' — bacteria that are resistant to a number of antibiotics. Some vancomycin-resistant bacteria have been found in hospitals, though, so it is important for scientists to continue to search for new weapons against bacteria.

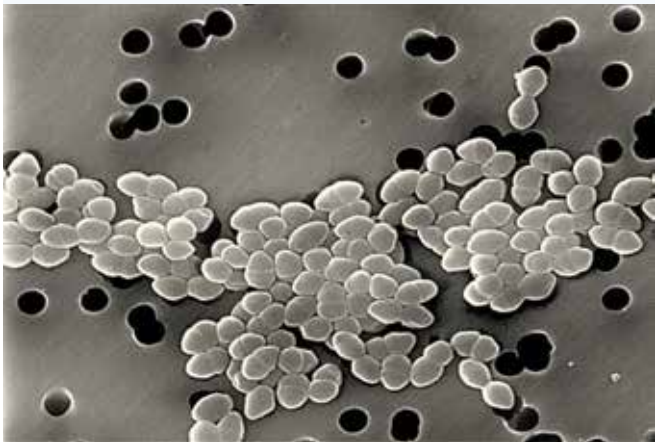
Another problem associated with the use of antibiotics is their impact on beneficial bacteria. The bacteria that live in our gut, in particular, play an important role in digestion. Antibacterial drugs do not differentiate between good and bad bacteria. That is the reason why taking antibiotics sometimes causes problems such as diarrhoea and stomach aches. Eating yoghurt or other foods containing friendly bacteria can help reduce the side effects of antibiotics.

In these photographs, bacteria were grown in penicillin for 30 minutes. The bacteria grew longer as shown at (b), but eventually ruptured (d), unable to divide due to the influence of the penicillin.



There is concern that overuse of antibiotics will increase the rate at which bacteria become resistant to a wide range of antibacterial drugs. Doctors are now more cautious in their use of antibiotics to treat infection. Antibiotics are used intensively in farming to treat sick animals but also as a preventative measure to reduce the risk of infection that may slow down the growth of animals. This practice is controversial as there are fears that the antibiotics may remain in the meat and could contribute to the problem of antibiotic resistance. Some consumers have responded to these concerns by buying only organic meat, despite the increased cost, although farmers who use antibiotics as a preventative measure argue that the risk to humans is minimal. Ensuring that animals are treated with different antibiotics from those used in humans and allowing a sufficient time gap between the last dose of antibiotics and slaughter are two ways to reduce the risk to human consumers.

Vancomycin-resistant bacteria



16.5 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. **Define** the term 'antibiotics'.
2. **Recall** what produces penicillin.
3. **Recall** who discovered penicillin.
4. **Outline** the role that Howard Florey played in the development of penicillin as a drug.
5. **Explain** how penicillin works.
6. **Outline** what superbugs are and why they are a cause for concern.

Think

7. **Describe** what would have happened if you had an ear infection before antibiotics were invented.
8. Why are antibiotics prescription-only medicines? (Prescription medicines can be purchased from a chemist only if you have a written prescription for that particular medicine from a doctor.) **Discuss** whether antibiotics should be available without a prescription.
9. What precautions must we all take to ensure that antibiotics remain useful to us?
10. **Assess** whether Florey would have been successful in extracting penicillin if he had been working on his own rather than as part of a team. What are the advantages and disadvantages of working in a team?
11. Antibiotics are used by some farmers as a preventative measure. **Discuss** whether this is a good practice, taking into account the benefits and disadvantages to farmers, consumers and other members of society.

Investigate

12. Meningococcal meningitis is a bacterial infection. **Investigate** why people can die from this disease despite antibiotics being readily available in hospitals.
13. Use the **Superbugs** weblink in the Resources tab to find out more about superbugs.

learnON RESOURCES — ONLINE ONLY

Complete this digital doc: Worksheet 16.3: Penicillin (doc-12493)

Explore more with this weblink: Superbugs

16.6 A little knowledge goes a long way

16.6.1 Improvements in technology

Improvements in technology have increased our knowledge of microbes. We can use this knowledge to solve problems that affect society.

Safe to drink

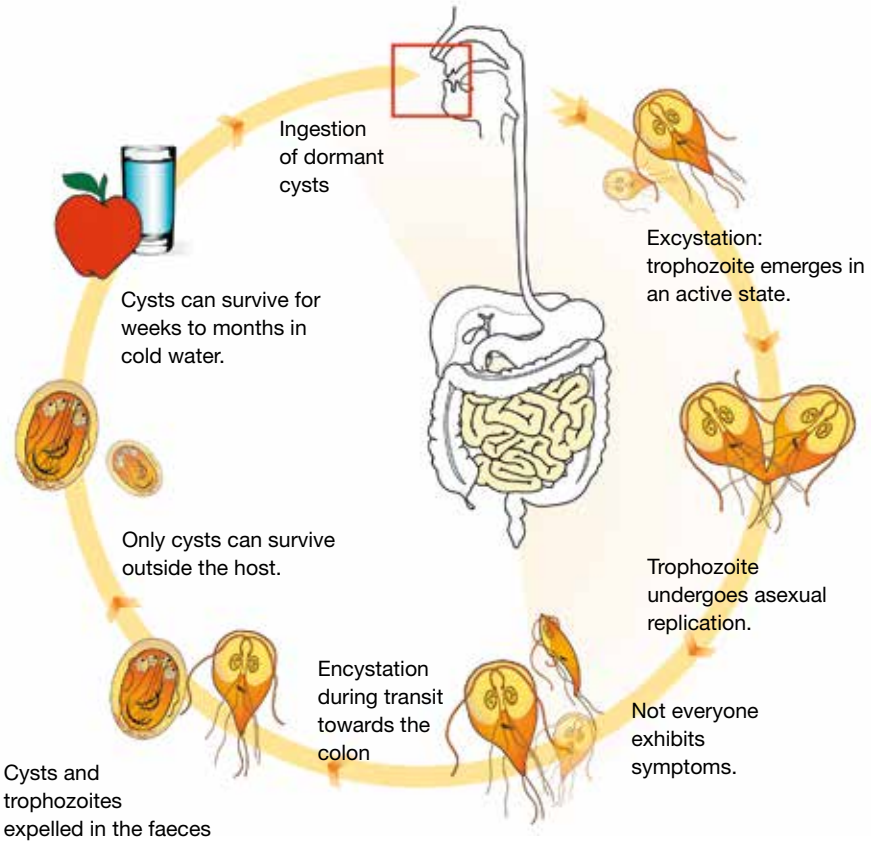
On page 645 we saw that the work of Snow and Koch was important in making people aware of the need for proper sewage treatment. Contamination of drinking water with human waste or other sources of dangerous micro-organisms can cause disease. Our water supply is generally quite safe and is tested regularly to ensure its quality. Occasionally, problems do occur and remind us that despite being tiny, micro-organisms can have a serious impact.

For a short period in 1998, Sydneysiders could not drink the water from their taps without first boiling it. Many public swimming pools were closed. Salad vegetables had to be washed with water that had been boiled and allowed to cool, and in some child care centres the children were not even allowed to wash their hands with water that had not been previously boiled. The culprit? Protozoans by the name of *Giardia lamblia* and *Cryptosporidium parvum*. Significant

Giardia lamblia are pear-shaped and quite large, usually being more than 6 µm in size.



Where do you fit into the life cycle of *Giardia lamblia*?



levels of these microscopic organisms were detected in the water supply. These parasites are the cause of one of the most common gastrointestinal infections in humans worldwide. *Giardia lamblia* use their flagella to move around, and they have a complex life cycle. The parasite can survive for a long period outside the body in an inactive form called a cyst. Once swallowed, the cyst is activated by your stomach acid and develops into the disease-causing stage. Using a huge sucker, they then attach themselves to the lining of your intestine, sucking your blood as their food source. After about ten days of infection, you could have a million of them living off your blood supply and causing symptoms associated with gastrointestinal complaints. Some of their reproductive cysts pass through your digestive system and are excreted, so that another host can become infected.

Solving the problem

To minimise the risk of infection by *Giardia* and *Cryptosporidium* the following measures can be used:

- Regular testing of the water supply so that outbreaks can be identified early and citizens can be provided with appropriate advice to avoid taking in protozoans
- Proper treatment of drinking water. Filtration can be used to remove *Giardia* cysts from water. To make filtration more effective, substances are added to the water to make small particles (including the *Giardia* cysts) clump together. *Cryptosporidium* cysts are smaller that *Giardia* cysts, so it is important to carefully select the type of membrane used to filter the water to ensure that both are removed. Chlorine and other disinfectants at sufficiently high levels can also inactivate these cysts.

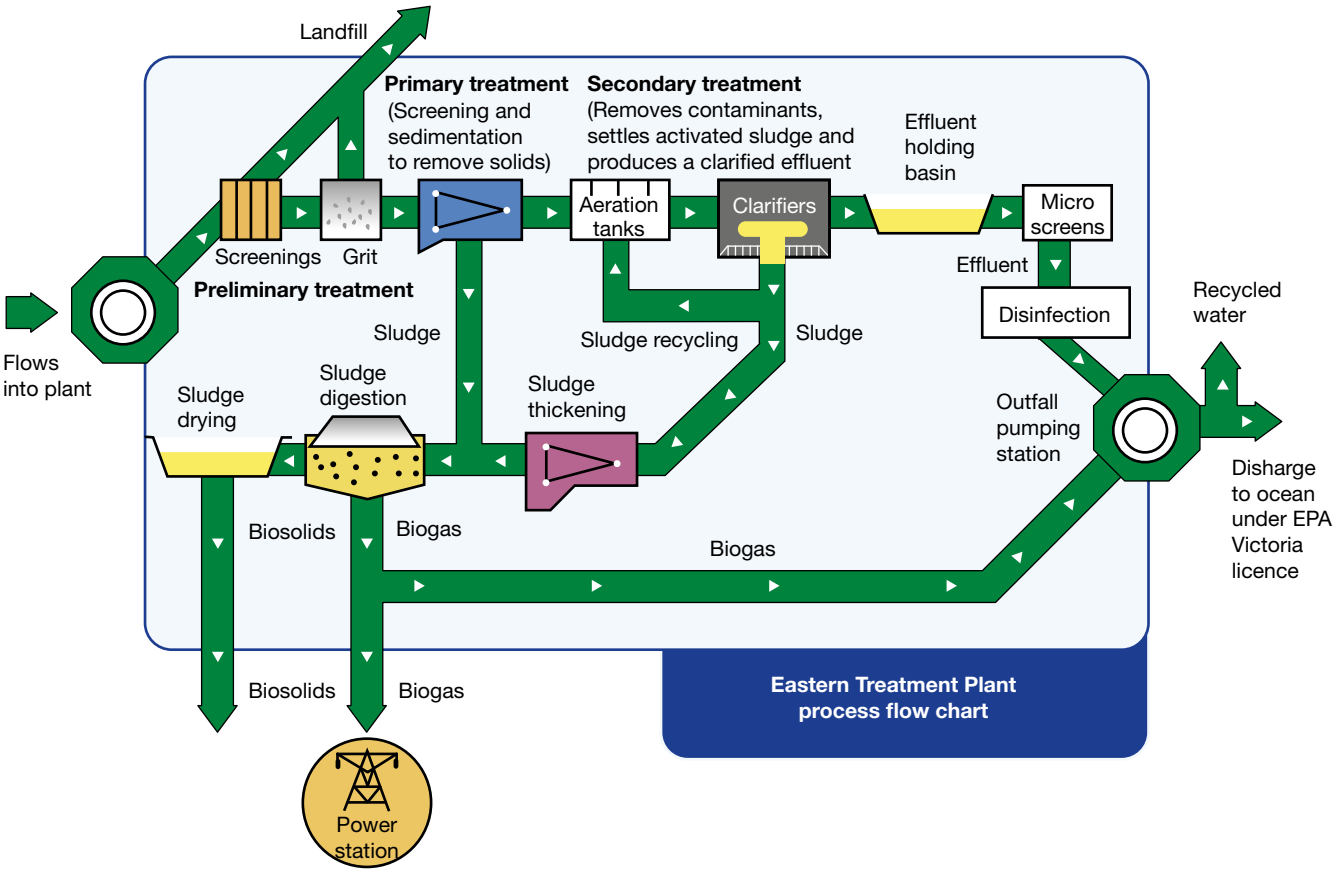
16.6.2 Sewage treatment

Ever thought about where the water goes when you flush the toilet? Unless you have a septic tank, it's likely that the water ends up in a system of pipes — the sewerage system — that takes it to a treatment plant. What happens at the treatment plant depends on where you live. Most of Sydney's sewage receives only primary treatment at the North Head Treatment Plant. Primary treatment involves screening and filtration to remove solids and sedimentation, a process where the water is held in tanks to allow oils to rise to the surface and small particles of solids to settle. The oil can be skimmed off and the sludge at the bottom is further processed. After this treatment has been applied, the effluent (waste water) is pumped out to sea a number of kilometres from the shore.

Some sewage treatment plants provide secondary and, in some instances, tertiary treatment of water. This has two advantages. Firstly, the treated water can be used for a variety of purposes rather than being pumped out to sea. Secondly, the sludge removed from the sewage can have useful applications as well. Secondary treatment uses bacteria. These feed on the organic material and use up some of the nutrients in the water. The water is then allowed to settle again. After further filtration and disinfection with chlorine, water that has gone through this process is clear. It can then be used on food crops that will be cooked before being eaten, on grazing lands and in industry. Further pathogen treatment leads to 'Class B' water, which may be used for watering land with restricted public use, for grazing land and for industry in which a higher standard of water is required. The sludge has a variety of applications as well. It can be used to make fertiliser. At the Melbourne Eastern Treatment Plant, biogas released from the sludge is collected and used as a fuel.

Tertiary treatment leads to 'Class A' water. It can involve several steps and, at the highest level, advanced technologies such as microfiltration, reverse osmosis and UV disinfection are used to make the water potable. At present, however, Class A water is used for food crops that are to be eaten raw, industrial processes, stock watering and toilet flushing. The diagram at the next page shows the processes involved in conventional sewage treatment and also in the low-cost treatment that is increasingly finding favour in rural areas. This latter method relies on carefully managed wetlands, micro-organisms and sunlight. This type of sewage treatment encourages biodiversity.

Water treatment at the Melbourne Eastern Treatment Plant



Can recycled water ever be safe?

There are two main types of contaminants in sewage — microbial contaminants (pathogens) from faecal wastes, and other contaminants such as pharmaceuticals, industrial chemicals and toxins arising from chlorination. Many of these are removed at the secondary treatment level. If any contaminants do slip through the process, they are measurable in parts per trillion (ppt). It is now possible to measure extremely low levels of contamination. Understanding this is important if we are to avoid being alarmed by their existence. Advocates of recycled water insist that the risks involved are extremely low.

16.6.3 Can I go for a swim?

You have probably heard that it is not a good idea to swim at some beaches after heavy rain. The reason has to do with the sewerage system. Sewerage pipes are designed in such a way that a blockage causes them to overflow into rivers and creeks rather than backing up into homes. In wet weather, rain water can get into the pipes, causing overflow. Untreated sewage ends up in rivers and creeks that run to the ocean.

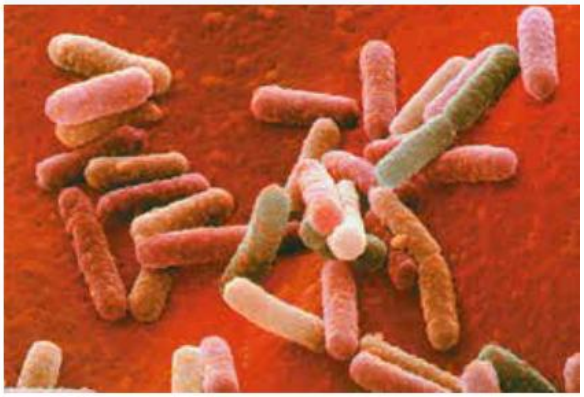
We can use our knowledge of bacteria to identify times when it is not safe to swim at the beach. *Escherichia coli* (*E. coli*) is a type of bacterium found in the intestines of warm-blooded animals, including humans. Most strains of *E. coli* are not harmful to humans, but their presence in

Sometimes, untreated sewage can overflow into waterways that run to the ocean.



water indicates that the water has been contaminated by faecal matter (poo!) produced by a warm-blooded animal. So high levels of *E. coli* in water collected from a beach are a good indication of sewage pollution. Wherever *E. coli* is found, more dangerous microbes could also be lurking, and swimming is not advisable.

Electron micrograph of *E. coli*



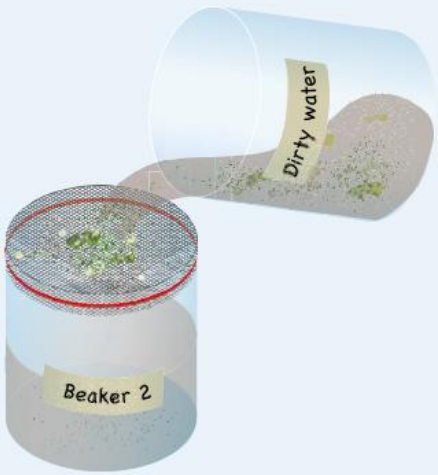
INVESTIGATION 16.3

Modelling a sewage treatment plant

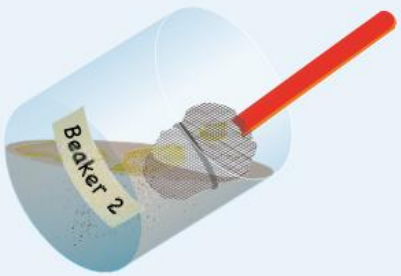
AIM: To demonstrate methods of removing impurities from water in a sewage treatment plant

You will need:

3 beakers
500 mL dirty water (500 mL warm water with the following added: contents of 2 teabags; actual tea bags, chopped up into small pieces; finely crushed dried leaves; half a handful of dirt; 2 tablespoons oil; 2 tablespoons sugar)
2 rubber bands
flyscreen mesh or tulle
cottonwool
spatula
effervescent antacid powder (such as Eno)
sterilising solution (such as Milton)
fine sand



- Half-fill beaker 1 with dirty water and label it 'Control'.
- Use the rubber band to attach a piece of the flyscreen mesh over the top of another beaker (beaker 2).
- Pour some of the dirty water into beaker 2 through the mesh. Observe which substances remain on the mesh and which pass through. Compare the water in beaker 2 with the control.
- Stir the water in beaker 2 vigorously, and then allow it to stand for at least 1 minute. Take a photo or draw a diagram, and label the substances that have sunk to the bottom and those that have floated to the top.
- Make a scraper by wrapping a wad of cottonwool around a spatula. Use a piece of flyscreen mesh and a rubber band to keep the cottonwool in place.
- Remove the mesh from beaker 2. Tilt the beaker gently and use the scraper to skim off the layer floating over the water into another beaker (beaker 3). (*Note:* The contents of beaker 3 should not go down the sink. Your teacher will advise you of the best method of disposal.)
- Carefully decant the water from beaker 2 into beaker 4, leaving the sludge behind that has settled at the bottom. Compare the water in beaker 4 with the control.
- Add 2 tablespoons of fine sand and two spatulas of antacid powder to beaker 4 and stir until the fizzing stops. The sand and antacid powder are meant to represent the bacteria that are normally used in secondary treatment. (*Note:* In this instance, we are not actually using bacteria for secondary treatment, but simulating the effect of the bacteria.)



- Allow beaker 4 to settle for at least 1 minute. Draw or take a photo of the water and label the substances that have sunk to the bottom. Compare the water with the control.
- Add 20 mL of sterilising solution to beaker 4. Compare the water with the control.

Discussion

1. Draw a flow chart to summarise the steps in this experiment.
2. Which step(s) in the above procedure model the following stages of sewage treatment?
   (a) Screening
   (b) Sedimentation
   (c) Secondary treatment
   (d) Disinfection
3. In this investigation we did not use real sewage.
   (a) Why would it be unsafe to use real sewage?
   (b) Which component of real sewage might have properties similar to:
      (i) tiny pieces of tea bag
      (ii) tea leaves and crushed leaves (*Hint:* These are organic matter.)
      (iii) oil?
4. In what ways was our model different from what happens in a real sewage treatment plant?
5. In a real sewage treatment plant it is important to add the correct dose of disinfectant to the water. What might be the consequences of adding too little or too much disinfectant?
6. Did we obtain pure water? What are some impurities that were left in the water? Would these be a problem if the water was to be recycled as drinking water? Explain your answer.

16.6 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.

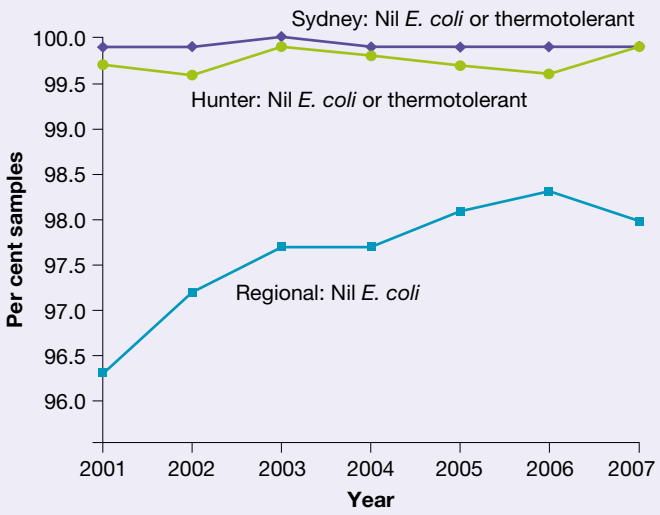
Remember

1. Why did Sydneysiders have to boil their tap water for a short period in 1998 before drinking it?
2. (a) **Describe** how *Giardia lamblia* obtains its food.
   (b) In which form can *Giardia lamblia* survive for weeks outside its host?
3. **Outline** why it is important to test the water supply for the presence of harmful micro-organisms including *Giardia* and *Cryptosporidium*.
4. **Outline** two ways of removing or inactivating *Giardia* cysts from drinking water.
5. **Explain** why it is not advisable to swim at some beaches after heavy rain.
6. **Explain** why protozoans that produce cysts are more likely to be transmitted via drinking water.
7. **Explain** why levels of *E. coli* are measured in water.

Skill builder

8. Use the graph below to answer the following questions.

Indicator bacteria counts in drinking water, Sydney, Hunter and regional water supplies, NSW 2001 to 2007



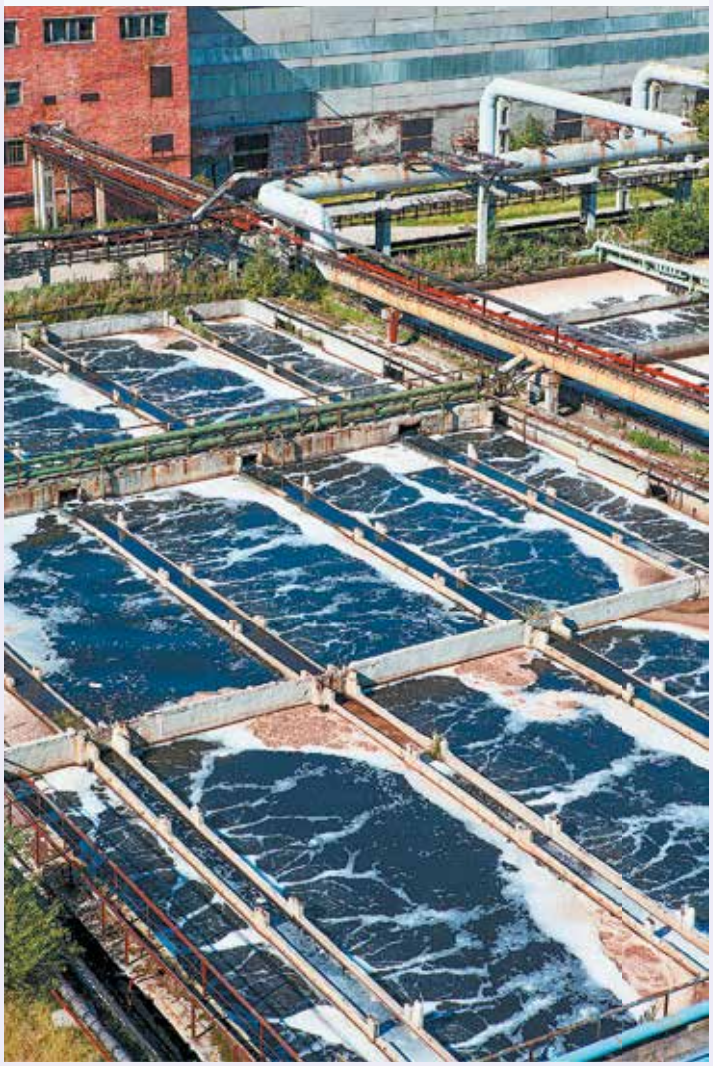
The graph shows the results of tests on drinking water from three water supplies. Samples of water were tested for *E. coli* and thermotolerant bacteria. A nil count means that no *E. coli* or thermotolerant bacteria were found. If the count is not nil, then it means that *E. coli* or thermotolerant bacteria were found. This indicates that the water supply may have been contaminated with sewage.

(a) Approximately what percentage of samples from the Sydney water supply had a nil count for *E. coli* and thermotolerant bacteria? Is this a good thing?
(b) Which water supply might give cause for concern? **Justify** your answer.
(c) Generally, has the quality of the regional water supply improved or become worse over time?

Research

9. Research and report on one of the following.
   (a) *Escherichia coli*
   (b) *Microcystis* spp.
   (c) *Giardia lamblia*
   (d) *Cryptosporidium parvum*
10. Find out how *E. coli* levels are measured and give examples of other micro-organisms that may indicate the presence of sewage pollution.
11. Research and report on the diagnosis, symptoms and treatment of:
    (a) cryptosporidiosis
    (b) giardiasis.
12. Use the **Water quality** weblink in the Resources tab to check out the latest daily water quality results from water filtration plants in Sydney and obtain current *Giardia* and *Cryptosporidium* data.
13. Use the **Treatment plant** weblink in the Resources tab to take a virtual tour of the Eastern treatment plant in Melbourne.

A water treatment plant



learnon RESOURCES — ONLINE ONLY

Explore more with this weblink: Water quality
Explore more with this weblink: Treatment plant
Watch this eLesson: Treating sewage (eles-0059)

16.7 Bacteria at your service

16.7.1 Bacteria can be useful

Increased knowledge of microbes and other living things has led to great advances in biotechnology — using living things to make products that are useful to humans. Microbes have been used in food production for a long time but, more recently, we have discovered ways of using bacteria to make products as varied as plastic, life-saving medicines, food additives and even anti-wrinkle treatments. We're even getting bacteria do some of our cleaning up.

Using bacteria to make food

There is evidence that cheese was already being produced in Europe 7000 years ago. Fragments of ancient pottery used for cheese making have been found in Poland. It is likely that the first cheese makers worked out that it was more convenient to transport and keep cheese than milk. They may also have found cheese easier to digest than milk.

In South America, archaeologists have found drinking vessels with traces of chocolate dating back to 600 BCE. Cocoa powder, which was used in those days to prepare unsweetened chocolate drinks, is produced from the fruit of the cacao tree. The fruit and seeds of the tree need to be fermented together. It is the action of microbes that gives chocolate its flavour. Of course, in these early examples of biotechnology, it was not known that micro-organisms were involved. The procedures had probably been discovered by chance and refined through trial and error.

Today, microbes are used to produce a wide range of products. Different strains of bacteria are added to milk to produce a variety of cheeses, yoghurts and other dairy products. Yeast is involved in the production of bread and alcoholic beverages. Products as diverse as sauerkraut, soy sauce and olives all require the action of bacteria. And, of course, chocolate is produced in larger quantities than ever.

Chocolate would not have its unique flavour without the action of microbes.



Xanthan gum is a common ingredient in ice-cream. It has the remarkable ability to thicken a liquid; only a tiny quantity of the powdered gum needs to be added. As little as 0.5 per cent will thicken a liquid such as salad dressing. A salad dressing with xanthan gum becomes less viscous when shaken so it can be poured, but it will thicken again when allowed to rest.



I'll have slime with that!

The next time you eat ice-cream or add dressing to a salad, take a close look at the

list of ingredients. Many ice-creams, sauces and some microwaveable meals contain an ingredient called xanthan gum, which is used as a thickener. Xanthan gum can be bought in powder form, but it is derived from ooze produced by a bacterium called *Xanthomonas campestris*. The bacteria produce xanthan gum as a mucus-like protective outer layer.

16.7.2 Bacteria making plastic

Plastic, it's everywhere! Cheap to produce and easy to make into a variety of shapes, films and foams, plastic has become a symbol of our modern way of life. Unfortunately, most plastics are derived from petroleum, a substance that is fast running out. Also, most plastics are non-biodegradable. Unlike paper and wood they are not broken down by the action of microbes and remain in the environment for a very long time after disposal. The solution? A new type of plastic that is made by bacteria and is biodegradable. A range of bacteria, including *Alcaligenes eutrophus*, produce plastic when grown in certain conditions. The bacteria are first allowed to replicate rapidly by giving them all the nutrients they need. Then they are placed in a different growth medium that lacks a particular nutrient. Instead of replicating, the bacteria begin to make plastic, which accumulates inside the bacterial cells. A plastic called PHB can be made in this way. It has similar properties to polyethylene, the plastic used to make plastic bags, but it is biodegradable.

Life-saving medicine

On pages 305–306 we saw that type I diabetes is a disease where the pancreas does not produce sufficient insulin. Treatment usually involves regular injections with insulin, either using a syringe or an insulin pump. Prior to the 1980s, insulin was extracted from the pancreases of animals, usually pigs or cattle. The insulin produced by these animals is very similar but not identical to human insulin, so in a few cases it caused immune reactions. Although many pigs and cattle are killed for meat, the pancreases of these animals are not a limitless resource. Also, within our society there is a range of views about the use of animal organs to produce medicines. Some patients or their families may object to being injected with insulin from pigs or cows for ethical or religious reasons.

Today, the main source of insulin is genetically engineered bacteria. Scientists have worked out that bacteria can make insulin provided that the human gene that codes for the manufacture of insulin is inserted in a plasmid (a ring of DNA) in the bacteria. As the bacteria replicate, they also make copies of the human insulin gene and they produce insulin.

16.7.3 Insulin

Insulin — who most deserved the Nobel prize?

Insulin was discovered in 1921, about 100 years ago. Before that, a diagnosis of diabetes was usually a death sentence. Once diagnosed, the only way to prolong a patient's life was to put them on a very strict diet, low in sugar and high in fat and protein. Most patients died within a year.

In 1889, two scientists called Minkowski and Von Mering showed that removing the pancreas of a dog caused it to develop diabetes and die. They also tried tying off the duct through which pancreatic juices flow from the pancreas into the small intestine. The dog did not develop diabetes; therefore the pancreas had to be producing a substance involved in regulating blood sugar, but that substance could not pass into the small intestine via the pancreatic duct.

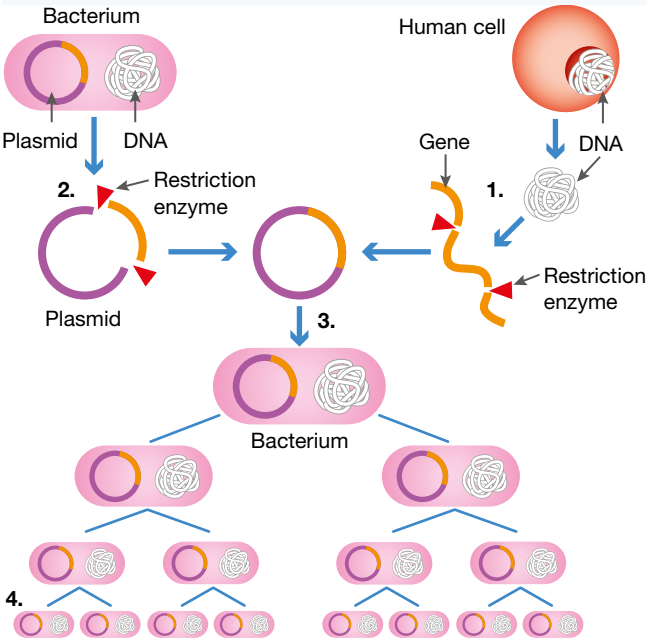
In 1921 Dr Frederick Banting, a surgeon, built on this experiment. He removed the pancreas from a dog, which then developed diabetes. He then injected the dog with an extract prepared from the pancreas of other dogs. The dog's blood sugar levels dropped and it regained energy. With regular injections of the pancreas extract, Banting was able to keep the dog free of symptoms.

Banting and another scientist called Best carried out further tests using pancreases from cattle rather than dogs. Their research was supported by Professor John McLeod from the University of Toronto who specialised in the study of diabetes. In 1921 another person called Bertram Collip joined their team. He was a biochemist and his task was to extract the insulin from the pancreas concoction that Banting and Best

had been using in their experiment. The next step was to test the insulin on human patients. Banting and Best initially tested the insulin on themselves. It made them feel weak and dizzy but otherwise unharmed. During this time, Collip continued experimenting on animals to determine dosages. Eventually, in 1922, insulin was tested on a 14-year-old Canadian diabetic who was near death. He responded well to the insulin. Further human testing was later carried out on volunteer diabetics.

In 1923, Banting and McLeod were awarded a Nobel prize for the discovery of insulin. Banting was upset that McLeod rather than Best had been acknowledged and so shared his cash prize with Best. In response to this McLeod shared his prize money with Collip.

Bacteria can produce human insulin if the insulin gene is inserted into the bacterial cells.



INVESTIGATION 16.4

Optimal conditions for fermentation

AIM: To investigate some of the factors that affect fermentation

The use of yeast to make bread is an example of biotechnology. Yeast converts sugars into alcohol and carbon dioxide gas. This is called fermentation. The bubbles of carbon dioxide gas released in fermentation cause bread dough to 'rise' and give bread its fluffy texture.

You will be investigating the effect of a factor of your choice on fermentation. Before you begin your investigation, plan your procedure by answering the following questions.

- Which factor will you investigate (examples: the effect of temperature, the amount of yeast suspension used, the addition of sugar or glucose powder to the standard bread dough)?
- Which variables need to be controlled? How will this be achieved?
- How will you compare the rate of fermentation? What will you measure? (*Hint:* Bread dough expands when fermentation occurs.)

The standard bread recipe below can be used as a starting point. Modify the standard recipe as needed to test the effect of the variable you have chosen to investigate.

You will need:

baking paper *sticky tape*
flour *salt*
glucose powder *sugar*
yeast suspension (prepared by combining a sachet of dry yeast with lukewarm water).

- Protect your desk by covering it with a large piece of baking paper stuck down with sticky tape.

Standard bread recipe

- Place about ½ cup flour and a pinch of salt in the middle of the piece of baking paper and form it into a well.
- Pour about 30 mL of yeast suspension into the well and mix by hand until a batter forms. You may need to add a small amount of water if the batter is too dry. If it is too sticky or runny add more flour. Ideally, you should be able to knead the dough without it sticking to your hands or the paper on the desk.
- Leave the dough to rise in a warm spot, such as on a sunny windowsill.

Discussion

1. Write a report for your investigation. Include the aim, method, results and conclusion.
2. Fermentation produces alcohol and carbon dioxide. Uncooked bread dough thus contains small amounts of alcohol. Explain why you cannot get drunk from eating large quantities of cooked bread.
3. Another technique used in baking to make batter fluffy is to add baking powder (sodium bicarbonate) to the flour. Self-raising flour contains some baking powder. Find out why baking powder causes bubbles to form in the batter.

16.7.4 Frozen in time

You have probably heard of celebrities having botox treatment, but did you know botox is produced by bacteria? Botox injections contain a protein produced by the bacterium *Clostridium botulinum*. The protein is a toxin that paralyses muscles. It is used in the beauty industry to paralyse some of the muscles responsible for facial expressions. This can prevent or improve the appearance of wrinkles. Botox is also used to treat a variety of medical conditions. In patients who have cerebral palsy, botox is injected into muscles that have become shortened as a result of overactivity and are thus locking joints in particular positions. This can improve mobility and greatly improve the patient's quality of life.

Botox injections paralyse the muscles responsible for some facial expressions.



16.7.5 Cleaning up the mess!

Oil spills can have devastating consequences, and cleaning up an oil-soaked beach can be a painstaking task as the oil clings to the rocks and soaks into the sand. French researchers are getting some help from hungry bacteria. The researchers have found that sprinkling oil-soaked beaches with fish meal might be an effective way of increasing the rate at which bacteria munch through the oil. They set up an experiment on a beach where they simulated an oil spill by pouring oil over four large square patches of sand. They sprinkled two of the squares with fish meal fortified with nitrogen and phosphorus. One square was left untreated and the fourth square was treated with the same detergent that was used to clean up after the *Exxon Valdez* oil spill. The scientists collected sand samples each week and found that the bacteria in the plots that had been sprinkled with fish meal were breaking down the oil faster than in the other two plots.

An Australian company called MBD Energy specialises in the use of algae and microbes to clean up messy situations. The company grows strains of algae and bacteria that have been selected for their ability to feed on particular waste, including water contaminated with heavy metals, mining waste and waste from certain types of farming businesses (such as piggeries). Some bacteria can also be used to convert methane from coal mines into carbon dioxide. The carbon dioxide, in turn, can be taken up by growing algae. The bacteria and algae feed on the waste and multiply. They can then be separated from the water and used for a range of applications, such as conversion to fuel or fertiliser.

Cleaning up beaches affected by an oil spill is a difficult task.



16.7 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. List some foods that are produced using bacteria.
2. What role do bacteria play in the manufacture of chocolate?
3. What is xanthan gum?
4. Name the raw material from which most plastics are produced.
5. **Define** the term 'biodegradable'.
6. **Outline** how the plastic PHB can be produced.
7. **Identify** the source of the insulin needed for the treatment of diabetes prior to the 1980s.
8. **Outline** how most of the insulin is produced today.
9. What is botox?

Think

10. **Explain** why some people may be reluctant to use insulin obtained from the pancreas of pigs or cows.
11. Why did Banting have to keep injecting the dog with pancreas extract to keep it healthy?
12. Banting carried out a number of experiments where he removed the pancreases of dogs. Many of the dogs died. **Discuss** whether animals should be used in medical research. In your answer consider the following.
    (a) Does the species of animal used make a difference?
    (b) Are there certain experiments that are justified, and others that should not be carried out?
    (c) Who should decide which experiments are allowed (scientists, group of citizens, university leaders)?
13. When Banting and Best tested the insulin on themselves, it made them weak and dizzy. Suggest why.
14. Eventually all medical treatments have to be tested on humans. **Outline** some considerations that may be taken into account when deciding which person should be the first test subject.

Skill builder

15. An experiment carried out by French researchers is described on page 662. In the experiment the researchers spread some fish meal over some parts of a beach that had oil spilled over it. Answer the following questions about the experiment.
    (a) What was the aim of the experiment?
    (b) What was the dependent variable?
    (c) Why was one of the plots left untreated?
    (d) Suggest why the fish meal increased the rate at which the bacteria broke down the oil.
16. Use the **Diabetic dog** weblink in the Resources tab to play a game that involves caring for a diabetic dog.

learnON RESOURCES — ONLINE ONLY

Explore more with this weblink: Diabetic dog

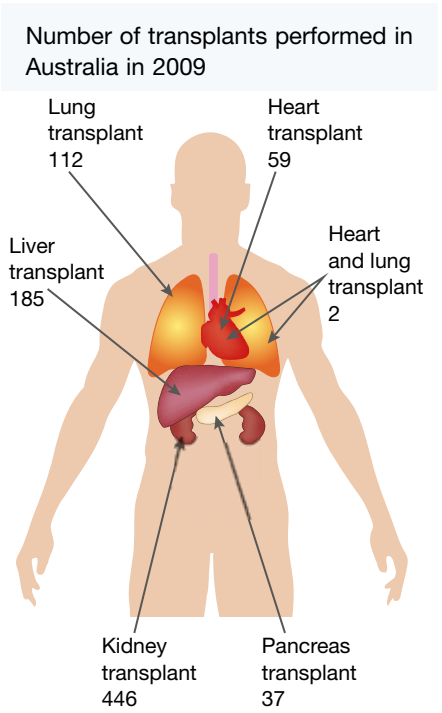
16.8 Replacement parts

16.8.1 Organ transplants

There are some body parts we can survive without. The loss of a finger, while making certain tasks more challenging, is not life threatening and does not affect general health (provided appropriate medical treatment is used to prevent infection). Your kidneys, liver, lungs, heart, and many other organs are essential for health. They carry out critically important functions. When these organs fail an organ transplant may be required. This involves obtaining a healthy organ from another person, usually a person who has recently deceased. It presents a number of medical challenges, but also raises ethical considerations. The biggest challenge to overcome is the shortage of suitable organs that are available for transplant. Growing spare organs from the patient's own cells may one day provide a solution to this problem.

16.8.2 Organ shortage

Currently there are close to 2000 people waiting for organs in Australia. Some are in hospital, experiencing very poor health. Others are able to keep living at home and go to school or work, but need regular medical treatment. For example people waiting for a kidney transplant may need to have regular dialysis (see page 326). Unfortunately there is a shortage of organs suitable for transplant and the average waiting list is between 6 months to 4 years, although this depends on the type or organ. Some of the reasons for the shortage of organs include:



- Since most organs are essential, they cannot be obtained from live donors. Kidneys are an exception. We have two kidneys and can manage quite well with just one. Provided the kidney is a match (see below), it is possible to donate a kidney to another person whose kidneys have failed.
- In most instances the organs need to be harvested from recently deceased patients, or patients who might be on life support with no brain function and no chance of recovery. The organs must be healthy. In instances when a patient is not on life support, there is only a short window of time after death before organs become damaged from lack of oxygen.
- In Australia organs can only be harvested with the permission of the family of the donor. Only about 60 per cent of families give permission. To overcome this a new procedure was introduced in 2000 for people to be on a donor register. People can register as an organ donor when applying for a driver's licence. Even if a person is on the donor register, their family can still refuse permission for organ donation, but in most instances, knowing that the deceased was registered as an organ donor makes the family's decision easier.
- The organ and the recipient must 'match'. The blood types must match. When you need a blood transfusion you can receive only certain blood types; the same rule applies to organ transplants. There are other ways the organ must match. Our immune system is designed to fight off bacteria, viruses and any other foreign particles that enter our bodies. The immune system can also cause the transplant organ to be rejected. By matching special proteins called antigens between the donor and recipients, the immune system will not fight off the donated organ as much, but even with careful matching the recipient will need to take drugs to suppress (turn down) their immune system for the rest of their life to prevent rejection of the organ.

16.8.3 Ethical issues

Ethical issues relate to whether something is the right thing to do. In many instances it is very clear whether an action is right or wrong. Killing a healthy person to harvest their organs for transplant would clearly be wrong. Sometimes it can be more difficult to decide, and opinions vary. Examples of ethical issues relating to organ transplants include:

- Is it necessary to ask permission from the donor's family before harvesting organs? Whose opinion matters most when family members disagree?
- Can a child under the age of 18 donate a kidney to a sibling? What about a parent or an elderly grandparent?
- Is it right for parents to have another child in the hope that the baby's kidney will be a match for his older sibling?
- Should the family of a recently deceased organ donor receive payment for the organs?

- Are there any organs that should not be transplanted (e.g. a face)?
- How can doctors be certain that an unconscious patient on life support has no chance of regaining consciousness. What tests should be carried out to determine whether a patient is likely to come out of a coma?
- Should certain people be given a higher priority on the waiting list for organs (e.g. children, parents of young children)?
- Do the recipients of organs have an obligation to look after the donated organ? Should there be consequences for organ recipients who do not take the required medicine or smoke and drink?

16.8.4 The future of organ transplants

The shortage of donor organs means that some patients die while waiting for an organ. The ultimate solution would be to grow organs in a lab. If the patient's own cells could be used issues relating to organ rejection would be addressed as well. One day it may be possible to grow complex organs such as hearts, kidneys and lungs, but for now scientists have had some success growing bladders from the patient's own stem cells. A bladder is easier to grow than other organs because it is hollow and has quite thin walls. Stem cells are cells that are not fully differentiated yet. They have not yet taken on their final form. They are found in certain parts of the body, including the bone marrow. Depending on the part of the body from which they are harvested they can be used to grow certain types of cells under the right conditions.

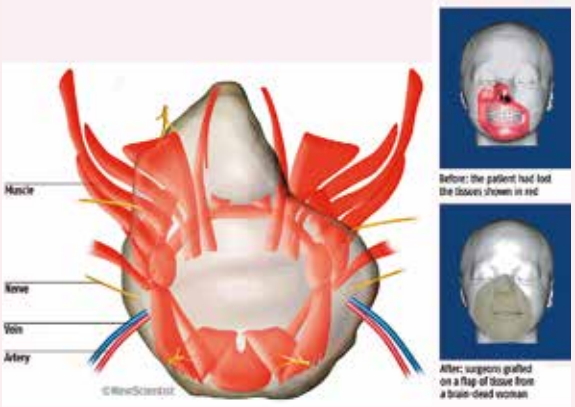
Another promising area of research involves growing transplant organs using a combination of the patient's own stem cells and animal organs. One day it may be possible to produce a heart suitable for transplant into a human, starting with a pig's heart. The pig's heart itself cannot be transplanted into a human because it would be rejected by the immune system. If all the flesh is removed from the heart, the remaining parts can be used as a scaffold on which human cells can be grown. If the patient's own cells

HOW ABOUT THAT!

Victor Chang was an Australian doctor who carried out some pioneering work in the field of organ transplants. He performed his first successful heart transplant in 1984 on a young girl named Fiona Coote. Victor Chang helped to establish the heart transplant unit at St Vincent's hospital in Sydney, he assembled a team of experts and developed new procedures and techniques that led to an improved success rate. He also developed an artificial heart valve and at the time of his death — he was murdered in 1991 — he was working on developing an artificial heart.

HOW ABOUT THAT!

In 2005 Isabelle Dinoire was mauled by a dog. Her injuries left her disfigured and unable to speak or eat normally. She became the first recipient of a face transplant. A triangular flap of tissue including a nose, lips and chin from a recently deceased woman was transplanted.



are used, the heart will not be rejected. A team of scientists from Minnnesota have already succeeded in making a beating rat heart using this technique. A year later they made further progress and produced rat hearts connected with some of the blood vessels they need.

16.8.5 Replacement parts made from man-made materials

While progress is being made towards producing replacement organs made from living tissue, some body parts can be replaced by parts made from synthetic materials. Damaged knee or hip joints can reduce mobility and are one of the most common reasons for having difficulty walking or climbing stairs in old age. It is sometimes possible to replace a damaged joint with an artificial joint made of plastic and titanium or ceramic.

A titanium and plastic hip joint



Following an amputation a person might be fitted with a prosthetic limb. These vary greatly depending on the type of injury and the person's lifestyle. Some prosthetics are designed to look very similar to the missing limb but may have limited function. For athletes, performance is usually more important. In fact some individuals might have a number of prosthetics that they use for different purposes. Australian paralympian John Eden has a choice of three legs: one for running, one for discus and one for everyday use.

Different types of prosthetics are suited to particular activities.



A team of scientists in Melbourne are testing a new type of prosthesis, one that screws onto the amputee's stump. Traditional artificial limbs have a socket that fits over the stump and are held by suction or using a belt or strap. This can irritate the stump and cause pain and other problems. The new type of prosthetic limb will address this problem and also give the wearer greater control over the limb.

16.8 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. Why is an organ transplant sometimes necessary?
2. What are immunosuppressant drugs?
3. **Outline** why a kidney can be donated by a live donor but a heart can be donated only by a deceased donor.
4. What materials are artificial joints made from?
5. What are the advantages of a prosthetic limb that can be screwed directly into an amputee's stump.

Think

6. **Explain** why doctors only have a short time frame in which to harvest organs after a person dies.
7. Recently scientists succeeded in transplanting an ovary that had been frozen then thawed out. It is hoped that in the future this may be possible with larger organs as well. What would be the benefits of being able to freeze transplant organs?

8. Pig and cow heart valves have successfully been implanted in humans. The valves are treated to prevent rejection. What would be some of the advantages of being able to transplant whole animal organs?

Discuss

9. Choose any two of the following questions and construct a PMI for each.
   (a) In Australia it is currently illegal to buy transplant organs either from a live donor or from the family of a deceased donor. Should it be legal to exchange money for organs?
   (b) When a person dies doctors should be allowed to harvest any useful organs without the need to seek permission from the relatives of the deceased.
   (c) The organ donor register was established in 2000. It allows Australians to register which organs (if any) they are willing to donate in the event that they die. Should it be compulsory for all Australians over the age of 18 to sign up to the register?
   (d) People who have a healthy lifestyle should be placed ahead of smokers, heavy drinkers and drug users on the organ transplant waiting list.
   (e) Children and parents of young families should be placed ahead of the elderly and people without dependants on the organ transplant waiting list.
10. Use the **Kidney transplant** weblink in the Resources tab to watch an animation and explain what a kidney transplant involves.
11. Use the **Religious rulings** weblink in the Resources tab to find out which religions are against organ donation.
12. How can you register to be an organ donor? Find out by using the **Organ donor register** weblink in the Resources tab.

learnON RESOURCES — ONLINE ONLY

- **Explore more with this weblink:** Kidney transplant
- **Explore more with this weblink:** Religious rulings
- **Explore more with this weblink:** Organ donor register
- **Watch this eLesson:** Heart valve (eles-0858)

16.9 Healthy careers

Science as a human endeavour

16.9.1 Careers in science

Most of us are familiar with a small number of careers in health and medicine, including nursing, pharmacy, dentistry and general medicine. However, a staff list for a hospital or medical research centre would show you that there are many more careers dedicated to getting people back to health. Numerous scientists work in the field of medicine and play an important role in identifying the causes of diseases and developing and testing treatments.

Scientists playing detective

Medical pathologists are scientists who study disease. They do tests to determine the cause of a disease. If you go to a doctor's surgery or hospital and have a sample of blood taken, a pathologist will organise technicians to run tests on the blood sample and prepare a report on the results of the tests. Pathologists also test tissue samples. If you had a mole removed, a pathologist would determine if the mole was harmless or a type of skin cancer likely to spread to other parts of your body. During surgery, a surgeon often sends body tissue to pathology. The results of pathology tests help the surgeon decide whether to finish the operation or keep looking for other things that might be wrong with the patient.

Some pathologists do post-mortem examinations ('postmortem' means 'after death'). A post-mortem examination is done if the cause of a person's death is unclear. The pathologist examines and tests the organs to determine the cause of death. Forensic pathologists are called in when foul play is suspected. They collect evidence that may lead to the conviction of criminals. In reality, only a small proportion of post-mortem examinations are concerned with solving crimes.

Medical scientists

Many scientists carry out research in the field of medicine. Some are employed by drug companies to develop and test new drugs to treat diseases. Others work for government agencies and universities on particular diseases. Teams of Australian scientists are currently trying to find cures for certain types of cancers and developing new vaccines.

16.9.2 Australian contributions to medical science

A team of scientists led by Howard Florey discovered how penicillin could be extracted, purified and produced (see page 650) and, recently, an Australian company has developed a treatment for some skin cancers (see page 504). Some other contributions to medical science by Australian scientists are summarised below.

- Aspro, the fizzy headache tablet, was invented by the Australian chemist George Nicholas. Aspirin itself had been developed earlier by the German company Bayer, but it was Nicholas who first produced the convenient Aspro tablets in Melbourne between 1915 and 1917. By the 1940s, it had become the world's leading headache treatment.
- Before the 1990s, it was widely believed that painful stomach ulcers were caused by stress. In 1982, Barry Marshall and Robin Warren showed that bacteria called *Helicobacter pylori* cause stomach ulcers and that it was possible to treat ulcers successfully with antibiotics. To prove that these bacteria cause ulcers, Barry Marshall swallowed the bacteria and soon developed symptoms associated with the formation of a stomach ulcer. Both scientists were awarded a Nobel prize in 2005 for their discovery.

An Australian scientist developed Aspro tablets.



Robin Warren and Barry Marshall were awarded a Nobel prize for their work on the cause and treatment of stomach ulcers.



Dr Fiona Wood, pioneer of 'spray-on skin'



- Dr Fiona Wood pioneered the development of spray-on skin to treat burns patients, including victims of the Bali bombing in 2002. She started a company that makes the spray-on skin using the patient's own skin cells. It can be applied to burnt areas of the body or to

scars. It is also used in cosmetic surgery. The main advantage of spray-on skin is that it reduces scarring. She was named Australian of the Year in 2005.

- The world's first vaccine against cervical cancer is also an Australian invention. It was developed by Professor Ian Frazer in the 1990s and was first approved for use in countries including the USA and Australia in 2006. The vaccine protects against a virus that is the cause of many cases of cervical cancers.

'Spray-on skin' in action



16.9.3 Career profiles: Clinical trials

First interest in science

Arianne's interest in science was first sparked in Year 4, after learning about famous scientists from the past. She has always been fascinated by how relevant science is to everyday life.

Some time ago, Arianne was a patient in clinical trials for asthma medication and has since taken an interest in the health sciences. Her father's work in the **pharmaceutical industry** has also given her an interest in this field of science.

Name: Arianne Lee
Job title: Clinical trials assistant
Field of science: Medical clinical research



The job

Arianne is a link between a research company that tests **pacemakers** and the hospitals that run the tests. She decides who will test the pacemakers and in which hospitals. Arianne seeks permission from ethics committees before any tests are conducted. These committees decide whether the tests are appropriate and also make sure that proper procedures will be followed. After collecting data from the clinical tests, she reports on the results.

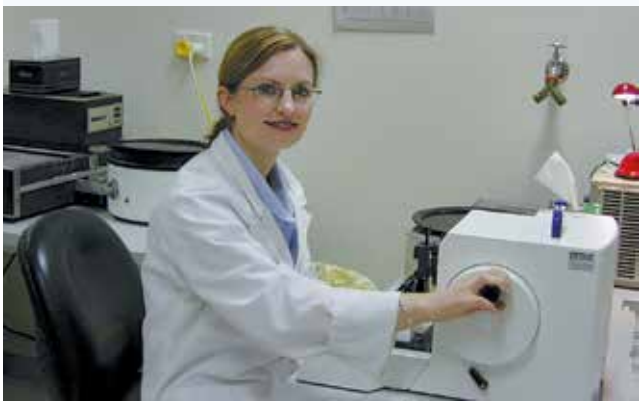
Study

Arianne has a Bachelor of Science. Her major areas are **physiology** and **pharmacology**. These areas are related to human biology and chemistry.

16.9.4 Career profiles: Histology

Paula Fisher is a **histologist**. Histology is the study of the **cells** and tissues that make up animals, including humans. Histologists look at small samples of cells and tissues under microscopes.

Name: Paula Fisher
Job title: Laboratory scientist
Field of science: Histology



The job

Cancer is a condition where cells grow abnormally. Each year, many people are **diagnosed** with cancer. Experts agree that the earlier treatment starts, the better the chances of survival.

Paula and her team help **engineers** to design machines. Their machines make diagnosing cancer a much faster process. Paula's job requires her to run the machines and make sure that the cells are clear and easy to see. This makes diagnosing cancer more accurate as well as faster.

Study
Paula enjoyed biology and chemistry at high school. She studied Applied Science at university and followed this up with a Graduate Diploma in Medical Laboratory Science. Many universities require students wanting to get into this field to have studied chemistry and one other science, usually physics or biology.

16.9.5 Careers in fitness

If you have a passion for fitness, an interest in learning more about the human body and you enjoy working with people, a career in the sport and fitness industry might be just the thing for you. For students achieving good results in Maths and Science, physiotherapy could allow you to combine your interests in science and fitness. Many physiotherapists work in hospitals or medical practices. They help patients recover from injuries or surgery. They can also prescribe exercise programs or other treatment for people who have recurring or chronic (long-term) pain, such as people with back problems. Some physiotherapists work closely with athletes and coaches to design training programs that reduce the risk of injury while maximising performance.

A physiotherapist at work



Entry into physiotherapy courses at university is highly competitive but there are other exercise-related careers. The fitness industry employs people with a range of qualifications to design exercise programs and motivate fitness club members to stick to their exercise programs. A degree in exercise science is an advantage when seeking work in the fitness industry but there are shorter courses that qualify you to become a personal trainer or group exercise instructor.

16.9 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. **Describe** the work of a medical pathologist.
2. **Explain** why post-mortem examinations are sometimes done by pathologists.
3. What medical trials did Arianne participate in herself?
4. What does a physiotherapist's job involve?

Think

5. Which sciences would you need to study in senior school to become a histologist?
6. **Identify** what the two professions described on pages 669–670 have in common.
7. In groups of two or three, make a list of the skills and other qualities people in the health sciences need.

8. Make a list of at least 20 careers that relate to health. For each career, **explain** in one sentence what that particular occupation involves.
9. Would doctors have prescribed antibiotics to treat a stomach ulcer before it was discovered that stomach ulcers were caused by a bacterial infection? **Justify** your answer.

Investigate

10. Interview a person who works in a health-related profession. **Summarise** the interview in a report with the following headings.
    (a) Name
    (b) Occupation
    (c) Place of work
    (d) A typical day at work
    (e) Personal attributes required for this occupation
    (f) Study required for this profession
11. Find out what ingredients make Aspro tablets fizz in water.

16.10 Review

Study checklist

16.10.1 Looking for patterns in health data

- **outline** some reasons for collecting and analysing health data from large groups of people **16.2**
- **explain** how scientific knowledge is contributing to the management and treatment of asthma **16.2**
- **interpret** graphs and tables **16.2**
- **outline** some reasons for researching allergies **16.2**

Microbes

- **describe** experiments carried out by Pasteur and Redi that supported the hypothesis that life cannot arise spontaneously but arises from other living things **16.3**
- **outline** some hygiene and sanitation practices that can help reduce the spread of disease **16.3**
- **describe** how bacteria reproduce **16.4**
- **outline** some of the conditions needed for bacteria to grow **16.4**
- **outline** the roles of Alexander Fleming and Howard Florey in the discovery of antibiotics **16.5**
- **discuss** the benefits of antibiotics **16.5**
- **describe** some ways that bacteria are used to produce food and other useful products **16.7**

Water treatment

- **explain** the importance of treating drinking water to reduce the spread of disease **16.6**
- **describe** some sewage treatment methods **16.6**
- **explain** why it is important to test water for the presence of certain micro-organisms **16.6**

Organ transplants

- **outline** some reasons why organ transplants are sometimes carried out **16.8**
- **discuss** ethical issues associated with organ transplants **16.8**
- **describe** some technological advances in the design of replacement body parts made from human-made materials **16.8**

Healthy careers

- **identify** some careers in the area of health science **16.9**
- **outline** significant medical discoveries made by Australian health scientists **16.9**

Individual pathways

ACTIVITY 16.1
Revising health science
doc-10589

ACTIVITY 16.2
Investigating health science
doc-10590

ACTIVITY 16.3
Investigating health science further
doc-10591

learnON ONLINE ONLY

FOCUS ACTIVITY

online only

Use EBSCO or another database to locate a newspaper or journal article about a recent development in the area of health science. Write a summary of the key points in the article.

Access more details about focus activities for this topic in the Resources tab (doc-10588).

16.10 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. Use an example from pages 638–639 to **explain** how analysing health data can lead to new knowledge about the cause and prevention of particular diseases.
2. **Describe** experiments carried out by Redi and Pasteur that showed that life cannot arise spontaneously from non-living matter.
3. Lister and Nightingale have both contributed to the improvement of hygiene standards in hospitals. **Outline** some of their main achievements.
4. Draw a diagram to show how bacteria reproduce.
5. Use the table below to answer the following questions.

Major causes of death in Australia

Year: 1919	Year: 2011
20% pneumonia	30% cancer
10% heart disease	20% heart disease
8% tuberculosis	8% stroke
7% accidents	7% Alzheimer's disease, dementia
5% cancer	4% asthma, emphysema, bronchitis
4% stroke	4% accidents
	3% diabetes

   (a) **Account** for the fact that the percentage of people dying from diseases such as pneumonia has decreased greatly since 1919.
   (b) **Explain** why the percentage of people dying from heart disease has increased so much.
   (c) What new additions to the major causes of death are listed in 2011?
   (d) **Explain** why you think each of the diseases in part (c) has emerged as a major killer.
   (e) **Account** for the fact that accidental deaths have decreased so much.
6. Charlotte wanted to find out if antibacterial soap really works. She prepared two agar plates. She swiped her fingers over the surface of plate A. She then washed her hands with antiseptic soap and swiped her fingers over the surface of plate B. She incubated both plates. Her results are shown below.
   (a) Write a conclusion for Charlotte's experiment.
   (b) Which plate was the control?

(c) What were the independent and dependent variables in this experiment?
(d) Which variables need to be controlled in this experiment so that it is a fair test?



7. Jossie wanted to find out the best conditions for growing bread mould. She put a slice of bread on each of five plates and left the plates in various locations around her house. Her results are shown below.

Location	Observations after 3 days	Observations after 6 days
Fridge	No mould	Small amount of mould
Freezer	No mould	No mould
Kitchen bench	Small amount of mould	50% of bread covered with mould
Top of fridge[(a)]	25% of bread covered with mould	75% of bread covered with mould
Bathroom cupboard[(b)]	50% of bread covered with mould	100% of bread covered with mould

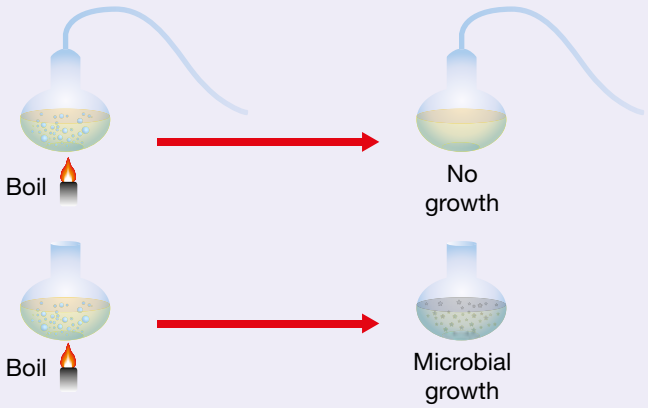
[(a)] The top of the fridge is warmer than room temperature.
[(b)] The bathroom is humid for most of the day.

(a) What conditions promoted the growth of mould?
(b) Why did the bread go mouldy a lot more slowly inside than on top of the fridge? Why did the bread not go mouldy in the freezer?
(c) Suggest some improvements to Jossie's experiment.

8. Equipment used in a doctor's surgery must be sterilised before use. Suggest why.
9. **Explain** why:
   (a) Antibiotics have greatly decreased the number of deaths from infectious diseases.
   (b) The discovery of penicillin is often used as an example of accidental discovery.
   (c) The work of Florey and his team was instrumental in making penicillin a useful treatment for bacterial infections.
10. When antibiotics first became widely available, doctors prescribed them to treat even minor coughs and colds. Today, doctors usually prescribe antibiotics only if the patient does not improve after a few days and the disease is highly likely to be caused by a bacterial infection. **Explain** why doctors have become more cautious.
11. **Explain** how increased knowledge about the transmission of diseases such as cholera can be used to prevent their spread.
12. Why is drinking water routinely tested for the presence of *Giardia* and *Cryptosporidium* in Australia?
13. **Distinguish** between primary, secondary and tertiary water treatment.
14. Choose two foods that are produced using microbes and **outline** how the microbes are involved in the production of these foods.
15. **Identify** two ways that bacteria might be used to address environmental problems.
16. Give two examples of body parts that can be replaced by parts made from synthetic (human-made) materials. Why is it important to continue researching ways of making better replacement parts from synthetic materials?
17. **Distinguish** between an artificial hand and a hand transplant.
18. **Explain** why patients often need to wait a long time for an organ transplant.
19. How might science provide a solution to the shortage of organs suitable for transplant?
20. Using organ transplants as an example, **explain** the meaning of the term 'ethical issue'.
21. **Describe** the type of work that is involved in the following health professions.
   (a) Pathology
   (b) Histology
   (c) Physiotherapy
22. **Outline** four examples of medical discoveries that have been made by Australian scientists.

Test yourself

1. Which of the following statements about asthma is not correct?
   (A) Cigarette smoke is a trigger for asthma.
   (B) Having a parent who has asthma does not increase your chance of developing the disease.
   (C) Babies who are put to sleep on their tummies are more likely to develop asthma.
   (D) An asthma attack involves widening of the air pipes in the lung. **(1 mark)**
2. A particular type of bacteria divides every 20 minutes. If you started with one bacterium, after 20 minutes, there would be two bacteria; after another 20 minutes, there would be four bacteria. How many bacteria would there be after 80 minutes?
   (A) 6
   (B) 6
   (C) 16
   (D) 32 **(1 mark)**
3. Which of the following foods uses microbes as part of its manufacturing process?
   (A) Chocolate
   (B) Bread
   (C) Ham
   (D) Cheese **(1 mark)**
4. The diagram below shows an experiment set up by Louis Pasteur. There was no microbial growth in the top flask because boiling the broth had killed all the microbes in the flask and the tube shaped like a swan's neck
   (A) prevented air from coming in contact with the broth.
   (B) prevented flies from laying their eggs in the broth.
   (C) prevented bacterial and fungal spores from falling into the broth.
   (D) trapped the heat inside the flask. **(1 mark)**
5. Which of the following statements about antibiotics is correct?
   (A) Antibiotics are an effective treatment for the flu.
   (B) Penicillin, a common antibiotic, is produced by mould.
   (C) Antibiotics were discovered about 200 years ago.
   (D) Alexander Fleming, the person who discovered penicillin, was Australian. **(1 mark)**



6. **Describe** an experiment you could do to test the following hypothesis: 'There are more bacteria on a kitchen chopping board than on a toilet seat.' **(3 marks)**
7. 'Increased knowledge about the human body and disease has resulted in advances in the field of medicine.' Use examples from this chapter to illustrate this statement. **(5 marks)**

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Complete this digital doc: Worksheet 16.4: Staying healthy puzzles (doc-12494)

Complete this digital doc: Worksheet 16.5: Staying healthy summary (doc-12495)

TOPIC 17
Student research project and skills

17.1 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.

17.1.1 Why learn this?

In this chapter, you will learn about the work of scientists and the skills needed to design, carry out and report on a scientific investigation.

LEARNING SEQUENCE

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Scientists use a wide variety of equipment to make accurate measurements.



Researching the CSIRO

Use the **CSIRO** weblink in the Resources tab to answer the following questions.

1. What is the CSIRO?
2. The CSIRO's website describes some of the research done by CSIRO scientists. Read the information provided for one area of research that the CSIRO is involved with and summarise this research in point form.
3. Form groups of three. Each student should explain to the other two students the area of research they have just read about. Try doing this without referring to your notes.

INVESTIGATION 17.1

Milk now or later?

AIM: To assess the cooling of coffee over time

You have just finished making yourself a cup of coffee when the phone rings. So that your coffee is as warm as possible, should you add the milk to your coffee now or after you have finished talking on the phone? Does your answer depend on the length of the phone call?

You will need:

kettle
2 identical cups
instant coffee
milk
2 thermometers or a data logger with 2 temperature probes
2 measuring cylinders

- Your teacher will assign a particular 'phone call' time to each group of students.
- Heat some water in a kettle and use it to make two cups of instant coffee. Make sure you use the same type of cup, the same amount of hot water and the same amount of coffee powder.
- Put a thermometer or temperature probe in each cup of coffee. If you are using a data logger, set it to collect results for at least 10 minutes.
- Measure 40 mL of milk in each of two measuring cylinders.
- Add 40 mL of milk to one of the cups.
- If you are using thermometers, record the temperature of the coffee in both cups every 30 seconds.
- After your phone call time has passed, add the milk to the second cup.
- Continue measuring the temperature in both cups every 30 seconds until 10 minutes has passed since you added the milk to the first cup.
- If you used thermometers, record your results in a table like the one below.

Time (minutes)	Temperature (°C)	
	Milk added at time 0	Milk added after 'phone call'
0		
0.5		
1		
1.5		

- Plot line graphs of your results on the same set of axes. Put time on the horizontal axis and temperature on the vertical axis.
- If you used a data logger, a graph is plotted automatically. If necessary, adjust the settings so that the graph shows the temperatures measured by both probes on the same set of axes. Put the graph into the results section of your experiment report or into your notebook.

A data logger can be used for this experiment.



Discussion

1. Does hot coffee cool faster than warm coffee? How can you tell from your graph?
2. Did the two lines on the graph cross at any stage? What does this indicate?
3. Write a conclusion based on your results.
4. Does the length of the 'phone call' affect the results? Compare your graph with those of other groups.
5. Why was it important to put exactly the same amount of water in both cups and to use the same type of cup?
6. What are the advantages and disadvantages of using a data logger for this experiment?
7. How could this experiment be improved? Explain your answer.

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Explore more with this weblink: CSIRO

17.2 Choosing a problem

17.2.1 What's the problem?

Choosing a problem to investigate can be the hardest part of a student research project (SRP). Ideally, the problem should relate to something you are interested in. You need to make sure that you can write a hypothesis for the problem you choose and that it can be tested by carrying out a scientific experiment.

The problem you choose to investigate should relate to science. It should be written as a question, and it should be something you do not already know the answer to; the problem should challenge you. On the other hand, you also need to make sure your challenge is achievable with the resources available at school. Some examples of problems suitable for a Year 8 student to investigate are shown in Possible student research project topics.

Some questions can be answered by doing just one experiment. Other problems are more complex and have many parts. To solve these, you may need to design and carry out a number of experiments. For example, if you are trying to find out what type of parachute will slow down a toy's fall most effectively, you may do an experiment to investigate the ideal material to use for the parachute, a second experiment to test the design of the parachute and a third to test the ideal size of the parachute.

17.2.2 Ethical considerations

Some research problems may not be appropriate to investigate due to ethical considerations. Ethics have to do with what is considered to be right and wrong. Different groups in society have varying opinions about certain types of research. While many people accept that testing medicines on animals is necessary, others feel very strongly that no research should be carried out on animals. Scientists involved in medical research are often required to have their research proposals reviewed by an ethics committee. The potential benefits of the research are taken into consideration. In your student research project, you should not do research that has the potential to cause stress or harm to people or animals. Your research should not be upsetting to people. This is particularly relevant if your research involves a survey.

POSSIBLE STUDENT RESEARCH PROJECT TOPICS

- Does the thickness of a rubber band affect how far it stretches? Do other features of rubber bands affect how far they stretch?
- What type of paper aeroplane flies furthest?
- What type of parachute slows a toy's fall best?
- Which plants make good acid–base indicators?
- What type of balloon rocket travels fastest?

- What is the best recipe for soap bubble mixture?
- Do tall people jump higher and further than short people?
- Does the amount of exercise you do affect your heart rate? In what way?
- What type of fabric keeps you warmest in winter?
- How do fertilisers affect the growth of plants?
- Does talking to plants improve their growth?
- Can plants grow without soil?
- What makes algae grow in an aquarium?
- What is the best shape for a boomerang?
- What type of wood gives off the most heat while burning?
- What makes iron rust?
- Which paint weathers best?
- Which battery lasts longest?
- Which type of glue is best?
- Which food wrap keeps food fresher?
- Which fabrics burn faster?
- How can the growth of mould on fruit be slowed down?
- Which concrete mixture is strongest?

Which parachute will slow the toy's fall more? Is the test fair?



Working in groups

Will you being doing your student research project individually or as part of a group? Working in groups has many advantages. You can divide up a task to get more work done in a short period of time. Each group member brings along their interests, expertise and skills and, if these are used effectively the quality of the work produced will be increased. When doing practical work, each team member can have a different role so that the task can be carried out efficiently. For example, *Investigation 17.2* would be difficult to set up individually, but a team of students can easily set it up.

Group work also has some pitfalls. Resentment builds up when the work is not divided up fairly. Group members might have different ideas about the best way to carry out the project and waste time trying to come to an agreement. An effective way to avoid some of these pitfalls is to assign each group member a role at the start of the project. Think about each group member's skills and decide on roles accordingly.

17.2.3 The aim of the game

Each of the experiments you do to solve your problem should have an aim. The aim of the experiment is the reason for doing the experiment. It is often more specific than the problem you are investigating and it should start with the word 'to'. Below are some examples of aims for experiments.

- To identify the flower pigment that makes the best acid-base indicator
- To determine whether the size of the sheet of paper used to make a paper aeroplane affects how far the plane will fly
- To compare the speed of balloon rockets gliding along different types of string
- To determine whether paper towel, cling wrap or aluminium foil is the best insulator of heat

What is your hypothesis?

A hypothesis is a sensible guess about how things work. It should relate to the aim and should be able to be tested with an experiment. The results of the experiment will either support (agree with) the hypothesis or not support (disagree with) the hypothesis. It is not possible to conclusively prove that a hypothesis is correct. When scientists make a hypothesis, they usually do a number of experiments to test that hypothesis. Sometimes, a number of teams of scientists test the same hypothesis with slightly different experiments. Even if the results of each experiment agree with the hypothesis, the scientists could never say that the hypothesis is proven to be correct. They would say that each experiment has provided further evidence to support the hypothesis.

Hypothesis or prediction?

A prediction is a specific statement about what we think will happen in the future or what we anticipate will happen in an experiment. For example, you might notice that the sky is grey and make the prediction that it will rain shortly. Before combining acid and magnesium you might predict that a gas will form. When testing your friends' heart rates, your prediction could be that James, who is the school cross-country champion, will have the lowest heart rate. A hypothesis is a more general statement. 'People who exercise regularly have a lower resting heart rate than those who do not exercise' is a hypothesis. Similarly, 'Purple flowers make good acid-base indicators' is also a hypothesis; it is a general statement about all purple flowers. A hypothesis can be used to make a prediction. 'Purple impatiens will make a good acid-base indicator' is a prediction. It is a specific statement about one particular type of flower.

17.2.4 Use your own observations

Your hypothesis and predictions should be based on observations you have made. They might also be based on your own reading. For example, if you are trying to design the best parachute for a toy, you should read about parachutes before writing your hypothesis. You might find out that light, closely woven fabric that does not increase in weight too much when wet makes better parachutes than heavy fabric that soaks up a lot of water. When walking home in the rain, you might observe that your cotton T-shirt soaks up a lot of water and becomes heavy, whereas your nylon jacket does not soak up water. As a result, your hypothesis might be: 'Closely woven nylon is the most effective fabric to use for a parachute'.

Fine-tuning your hypothesis

A statement that cannot be tested with a scientific experiment is not a suitable hypothesis. The statement 'People born in January are more conscientious than others' is not a good hypothesis unless you can find a reliable way to measure conscientiousness. The statement 'People born in January work more hours than others' is a better hypothesis because the number of hours worked is something that can be measured. Similarly, the statement 'Watching television makes you fat' would be difficult to test scientifically; however, the statement 'Children who watch more than two hours of television each day are more likely to be overweight than children who watch less than two hours' could be tested scientifically.

'Aeroplanes made from cardboard fly better than those made from paper' is not a suitable hypothesis because 'fly better' has not been defined so cannot be tested scientifically. 'Fly better' could mean fly further, fly in a straighter line or stay in the air longer. A better hypothesis would be 'Aeroplanes made from cardboard fly further than those made from paper.'

INVESTIGATION 17.2

The balloon rocket

AIM: To investigate variables that affect a balloon rocket

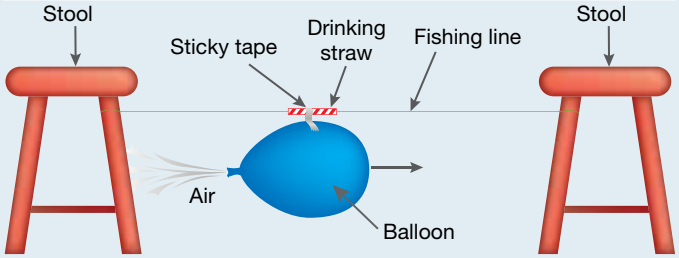
You will need:

2 stools
straw
sticky tape
fishing line
balloon
stopwatch
different types of string

- Thread the fishing line through the straw and tie the ends around the legs of two stools or chairs as shown below.
- Blow up the balloon and, while holding it closed, use a piece of sticky tape to attach the balloon to the bottom of the straw.

- Release the balloon so that the air can escape. Use the stopwatch to measure the time taken for the balloon to reach the end of the fishing line.

Does a balloon rocket glide faster along a fishing line or a string?



- Design and carry out an experiment to investigate whether the type of string used in this experiment affects the speed of the balloon rocket. When designing your experiment, think about making your experiment fair and repeating your experiment to ensure that your results are reliable.

Discussion

1. Write an aim and a hypothesis for your experiment.
2. Apart from the type of string, what are some other factors that might affect how fast the balloon rocket travels from one end of the string to the other? These are the variables for the experiment.
3. To make the experiment fair, only one variable (the type of string) should be changed. All other variables should be controlled (kept the same). Complete the table below. The first line has been completed for you.

Variable	How this variable was controlled
Amount of air in balloon	We blew up the balloon to the same size each time.

4. Tabulate your results. Calculate the average time taken for the balloon to reach the end of the string for each type of string.
5. Do your results support your hypothesis?

17.2 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. Copy and complete the following statements using these words: aim, to, hypothesis, problem, predictions, support, observations, prove, tested.
   (a) An aim always starts with the word _____.
   (b) A _____ is usually worded as a question to answer.
   (c) The results of an experiment can _____ a hypothesis but they never _____ that the hypothesis is correct.
   (d) A _____ is an educated guess about how things work.
   (e) The _____ of an experiment is the purpose of the experiment.
   (f) A hypothesis can be _____ by carrying out a scientific experiment.
   (g) We can use a hypothesis to make _____.
   (h) A good hypothesis is based on_____ and often also on research.
2. **Distinguish** between the terms ‘hypothesis’ and ‘prediction’.

Think

3. **Classify** each of the following statements as an aim, a hypothesis, an observation or a prediction.
   (a) Mould grows fastest in warm and humid environments.
   (b) No mould will grow on bread if it is stored in the fridge.
   (c) To find out the temperature at which mould grows fastest

(d) After 5 days, 50 per cent of the slice of bread stored at 35 °C was covered in mould.
(e) After 3 minutes, the temperature of the coffee in the ceramic cup had dropped from 80 °C to 63 °C.
(f) Ceramic is a better insulator than plastic.
(g) To find out if ceramic is a better insulator than plastic
(h) Coffee will cool down faster in the plastic cup than in the ceramic cup.

4. Is each of the following statements a suitable hypothesis? If not, **justify** your answer.
(a) White chocolate tastes better than dark chocolate.
(b) Washing powder X removes tomato sauce stains faster than washing powder Y.
(c) Plants grow faster under red light than under green light.
(d) Sagittarians are nicer people than Leos.
(e) Playing video games increases the muscle strength in your thumbs.
(f) Playing video games affects the development of social skills.
(g) Science teachers are more interesting people than English teachers.
(h) Science teachers perform better in IQ tests than English teachers.

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Complete this digital doc: Worksheet 17.1: Starting an investigation (doc-12496)

17.3 Thinking about your problem

17.3.1 Thinking tools

Much of a scientist's work involves thinking about problems and trying to come up with solutions. Sometimes ideas seem to pop into your head when you least expect it, such as when you are out walking the dog. In some instances, though, thinking needs to be an organised process. The thinking tools described on the next few pages will help you make a start on your student research project.

Looking from all sides: PMI

PMI stands for plus, minus, interesting. A PMI is a thinking tool that encourages you to look at an idea from a number of perspectives before making a decision. Use the following steps to construct a PMI on a particular topic.

1. Write your topic or problem at the top of the page.
2. Draw three columns underneath the topic.
3. Fill in the three columns with good things and bad things about the topic or problem and things you find interesting but are neither good nor bad.

Imagine that a student was thinking of choosing the following problem for their student research project 'Do guinea pigs eat more food when the weather is cold?' The example below shows a PMI that the student used to decide whether to choose that particular problem for her project.

Choosing the following problem for my SRP: Do guinea pigs eat more food when the weather is cold?

Plus	Minus	Interesting
• I have four guinea pigs at home so I don't need to buy guinea pigs. • I know a lot about guinea pigs and I enjoy looking after them.	• I don't want to make my guinea pigs uncomfortable or sick by exposing them to extreme temperatures. • Four guinea pigs may not be enough to provide reliable data, and my mum will not let me buy more guinea pigs. • My Science teacher may not approve an SRP that involves animals.	• How will I measure how much food the guinea pigs have eaten? • I may need a food dish that the guinea pigs cannot tip over. 

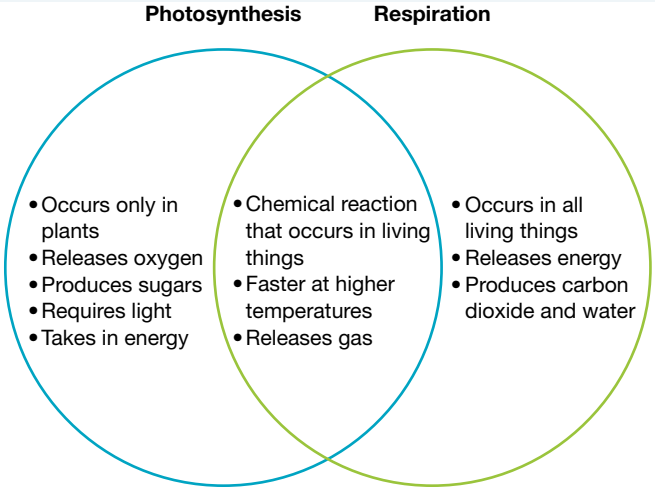
17.3.2 How ideas overlap: Venn diagrams

Venn diagrams are often used in mathematics, but they can be useful to scientists as well to show the common points between different ideas or concepts. Use the following steps to draw a Venn diagram for two topics.

1. Draw two overlapping circles with the topic written above each circle.
2. In each circle, write down ideas that relate to each topic.
3. Write ideas that relate to both topics in the overlapping section.

Below is a Venn diagram that shows some of the similarities and differences between respiration and photosynthesis.

A Venn diagram



17.3.3 Mapping your thinking

Once you have selected a problem, a bubble map, cluster map or mind map can help you organise your thoughts. These three thinking tools have many similarities and some key differences.

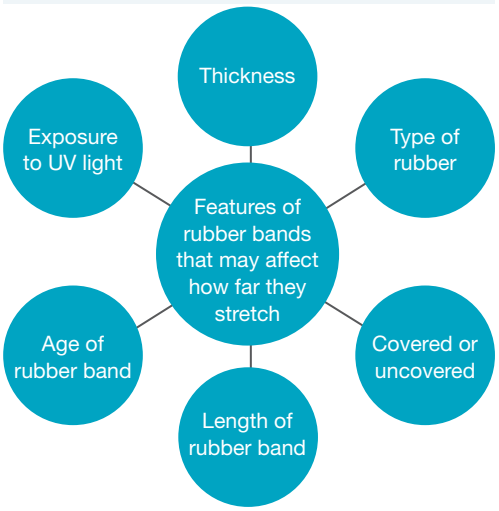
Identifying key ideas: single bubble maps

A single bubble map is the simplest way to map your thinking. Use the following steps to construct a bubble map on a particular topic.

1. Write your topic in the middle of the page.
2. Around the topic, write down any ideas that relate to your topic and join these ideas to your topic using lines.

In the example at right, a student created a single bubble map to organise her thinking about the problem she chose for her SRP: 'Which features of rubber bands affect how far they stretch?'

Single bubble map



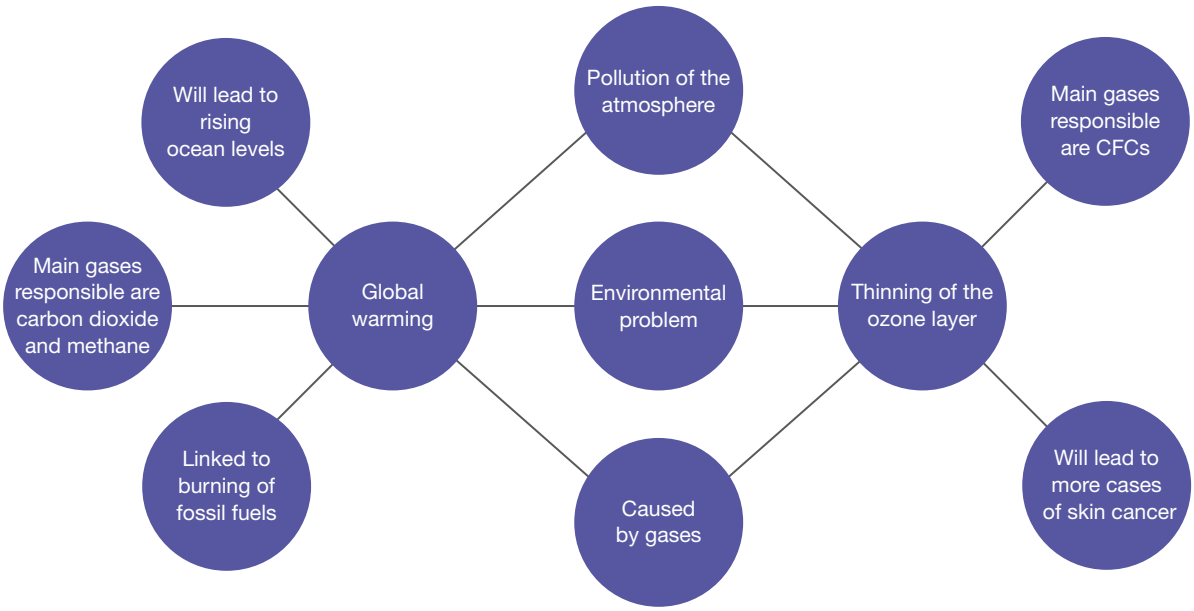
17.3.4 Identifying similarities: double bubble maps

Like Venn diagrams, double bubble maps can be used to show things that are common to two different topics. Use the following steps to construct a double bubble map.

1. Create separate single bubble maps for the two topics that you are comparing.
2. Identify the characteristics that are the same or similar.
3. Redraw to create a double bubble map by placing the similar bubbles in the middle.

The example below shows a double bubble map for two important environmental issues: thinning of the ozone layer and global warming.

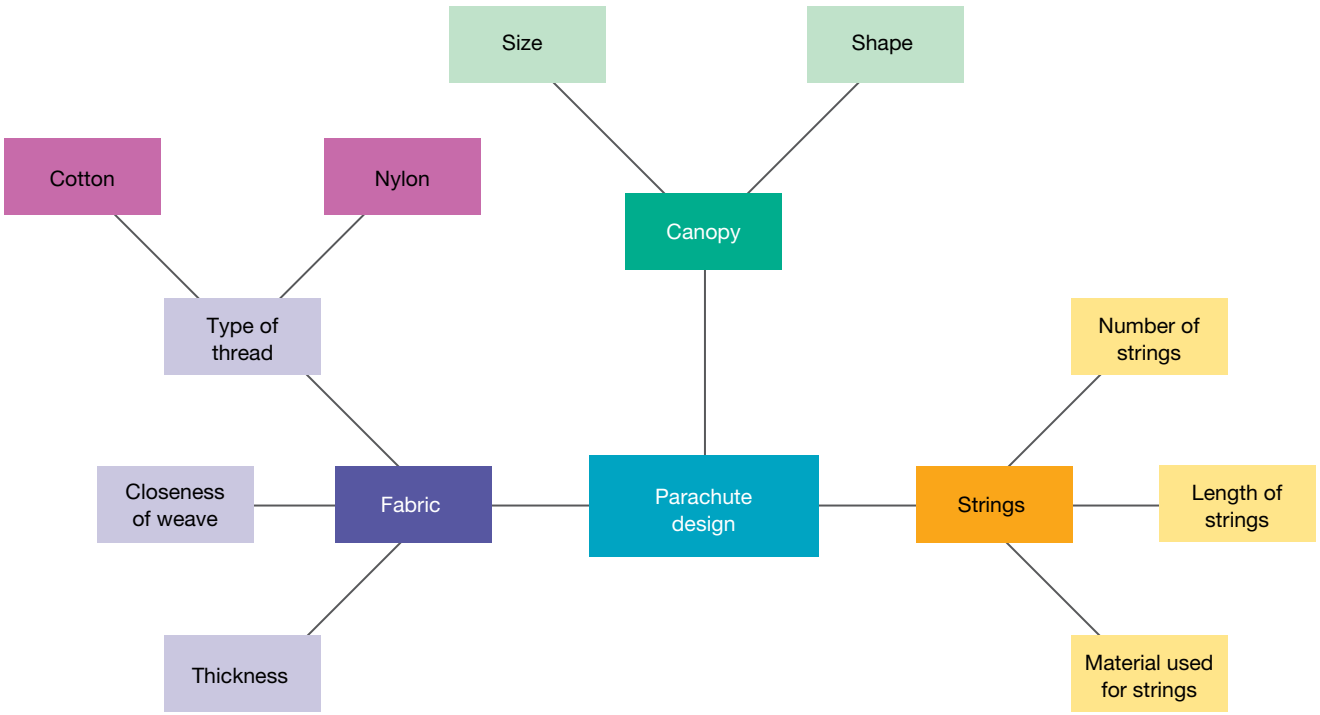
Double bubble map



17.3.5 Stimulating ideas: cluster maps

A cluster map starts in the same way as a bubble map, but each of the bubbles around the central topic can itself have other ideas linked to it. Use the following steps to construct a cluster map.

A cluster map



1. Think of a topic and write it in the middle of a sheet of paper.
2. Around your topic, write down any ideas that link with it. Draw lines from the ideas to your topic.
3. Write down new ideas that are related to your first ideas, and link them with lines.

The cluster map on the previous page was created by a student who chose the following problem for her SRP: 'Which parachute design will slow down a toy's fall most effectively?'

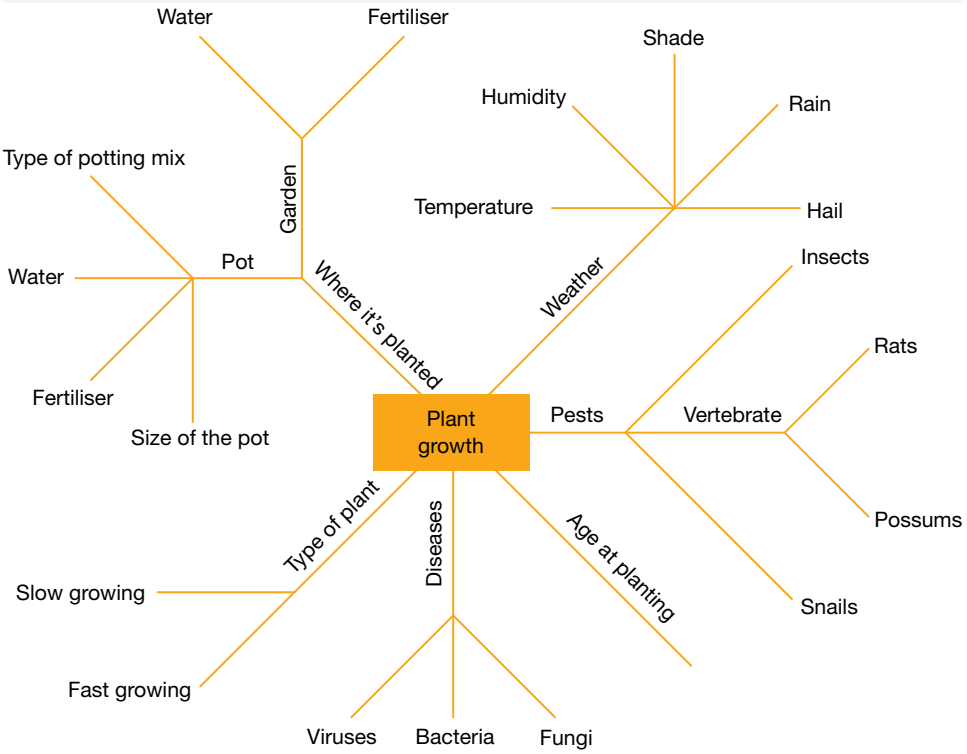
17.3.6 Exploring and summarising ideas: mind maps

A mind map is similar to a cluster map but it also has the relationship between the ideas written on the lines that join them. Creating a mind map for a particular topic is a great way of revising that topic to prepare for an examination. Use the following steps to construct a mind map.

1. Write your topic in the middle of a sheet of paper and draw a number of lines branching out from it.
2. Think of some main ideas related to the topic and write one on each branch.
3. Draw a number of lines branching from each of your main ideas.
4. Think of words or terms related to one of your main ideas and write one on each branch.
5. Continue adding branches until you run out of ideas.
6. You can decorate your map with colour, clip art, drawings, photos etc. to make the ideas and links clearer.

An example of a mind map is given below. It was used by a student to revise the plant growth topic. A mind map could also help you plan your SRP.

A mind map



17.3.7 Linking ideas: concept maps

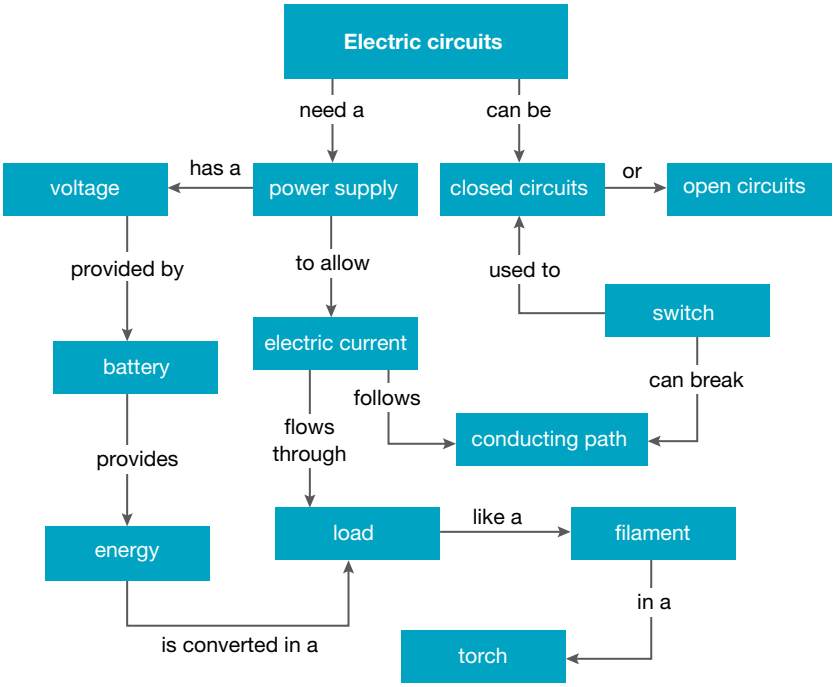
A concept map is similar to a mind map in that they both show the relationship between ideas in a topic. However, a concept map also explains the relationship between elements, with statements written on the links. Use the following steps to draw a concept map.

1. Write down all the ideas you can think of about a particular topic.
2. Select the most important ideas and arrange them under your topic heading. Link these main ideas to your topic and write the relationship along the link.

3. Choose ideas related to your main ideas and arrange them in order of importance under your main ideas, adding links and relationships.
4. When you have placed all of your ideas, try to find links between the branches and write in the relationships.

An example of a concept map is given below. It illustrates some of the important ideas and links associated with electric circuits.

A concept map



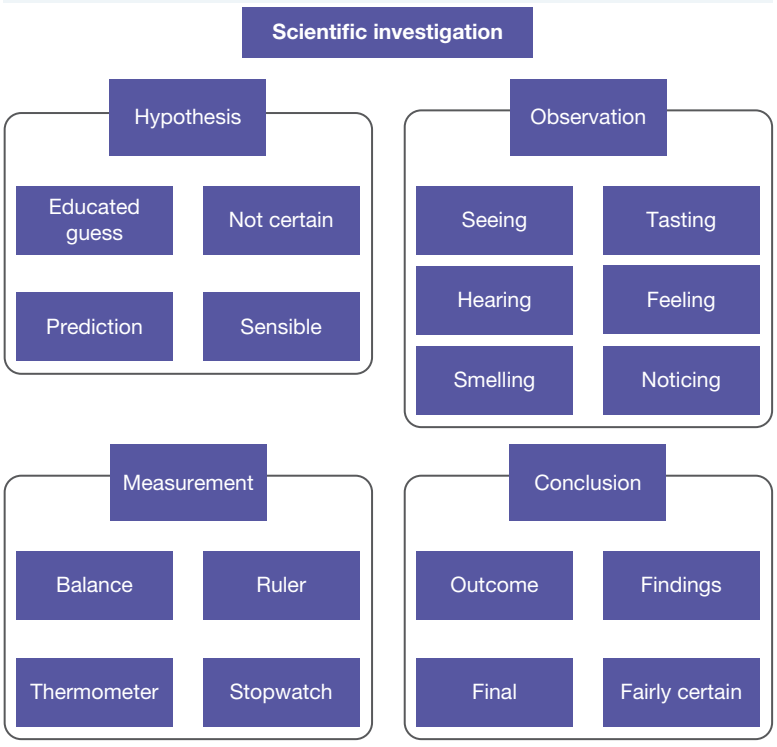
17.3.8 Sorting ideas into groups: affinity diagrams

An affinity diagram helps you to group common ideas or viewpoints. Use the following steps to construct an affinity diagram on a particular topic.

1. Think about a topic and write any ideas you have onto small pieces of paper.
2. Examine your pieces of paper and put similar ideas into groups. Feel free to rearrange your groups until you are happy with them.
3. Think of names for your groups.

An example of an affinity diagram is shown at right. Each category name represents an important part of scientific investigations.

An affinity diagram

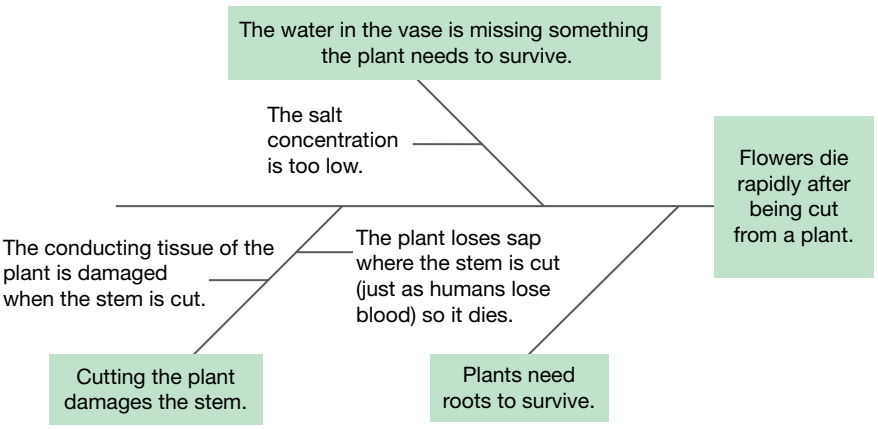


17.3.9 The cause of it all: fishbone diagrams

A fishbone diagram is particularly useful if you are trying to establish the cause of an event. Use the following steps to construct a fishbone diagram on a particular event.

1. Think of an event that you do not know the causes of.
2. In pairs or a team of four, organise your list of causes into groups.
3. Write the event that you are analysing as the 'fish's head' of a fishbone diagram. Your groups of causes then become the main 'bones' of the diagram, one bone for each group.
4. Write the title of each of your groups of causes on its relevant 'fishbone'.

A fishbone diagram



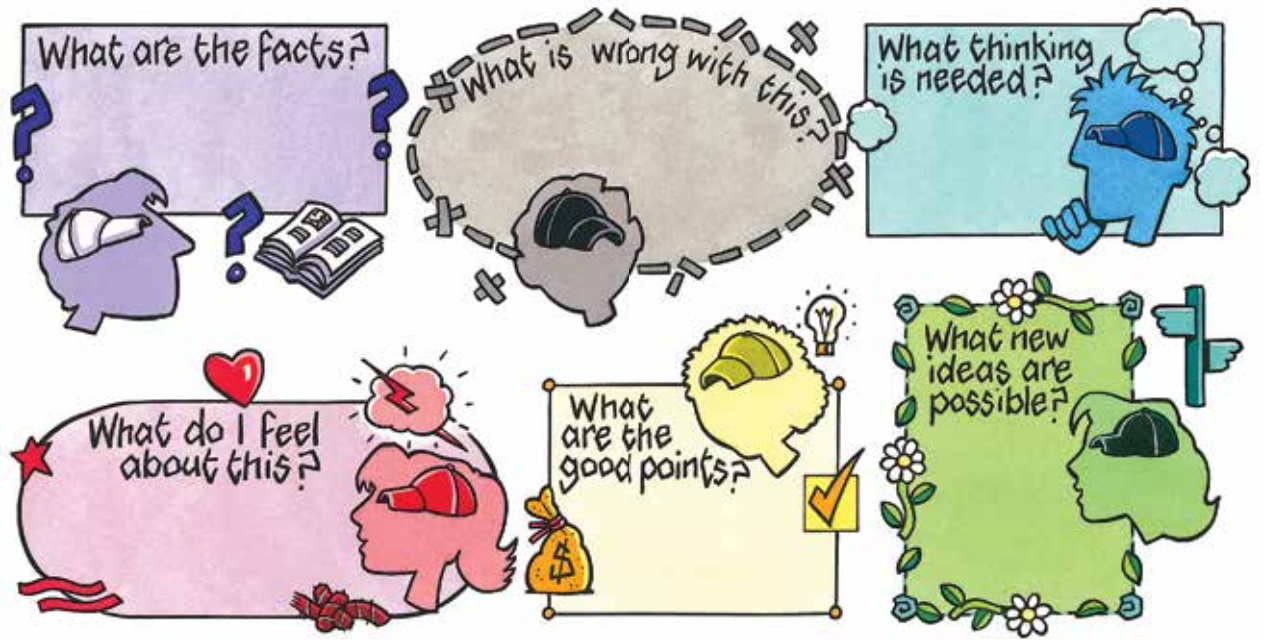
5. Write the causes on the smaller 'fishbones' that are joined to the sides of the main bones. (You can attach a cause to more than one bone or group of causes.)

Charlotte constructed the fishbone diagram above for her SRP problem: 'How can I keep cut flowers looking fresh for the longest possible time?' In her fishbone diagram, she has considered the reasons why flowers die rapidly after they have been cut from a plant.

17.3.10 Thinking with different hats

There are a number of very useful tools that can help develop your thinking. One of these was created by a great thinker by the name of Edward de Bono. He developed the idea of using different coloured **thinking hats** for different types of thinking. These hats don't even have to be on your head. The idea behind each hat just needs to be *in* your head.

The six coloured thinking hats



The following example shows how your thinking hats can be used to discuss whether expensive space exploration should continue.

PROBLEM: SPENDING BILLIONS OF DOLLARS ON SPACE EXPLORATION

Red hat:	How do you feel about all the money spent on exploring space?
Yellow hat:	How do we benefit from space exploration?
Black hat:	What's wrong with spending billions on space exploration?
White hat:	What information do we need?
Green hat:	What other things could we spend the money on?
Blue hat:	What can be gained from space exploration in the future?

17.3 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 PMI stand for?
2. **Identify** a type of diagram that consists of two overlapping circles.
3. **Distinguish** between bubble maps, cluster maps and mind maps.
4. **Compare** Venn diagrams with double bubble maps.

Think

5. **Construct** a PMI for each of the following ideas.
   (a) School students should not wear a uniform.
   (b) School canteens should sell only healthy food.
   (c) Parents should be fined if their children are sunburned.
   (d) The legal driving age should be changed to 21.
   (e) All high-school students should be given a free computer paid for by the government.
6. **Construct** a Venn diagram with one circle labelled 'Plants' and the other 'Animals' and complete using features of plants and animals. (*Hint:* See topics 2 and 4.)
7. (a) **Construct** a bubble map for the topic 'The solar system'. (*Hint:* See topic 6.)
   (b) Add additional bubbles to change your bubble map into a cluster map.
8. Choose one of the topics you studied in Science this year and, working in groups of three to four students, **construct** a mind map for that topic.

17.4 Organising your thinking

17.4.1 Timelines and Gantt charts

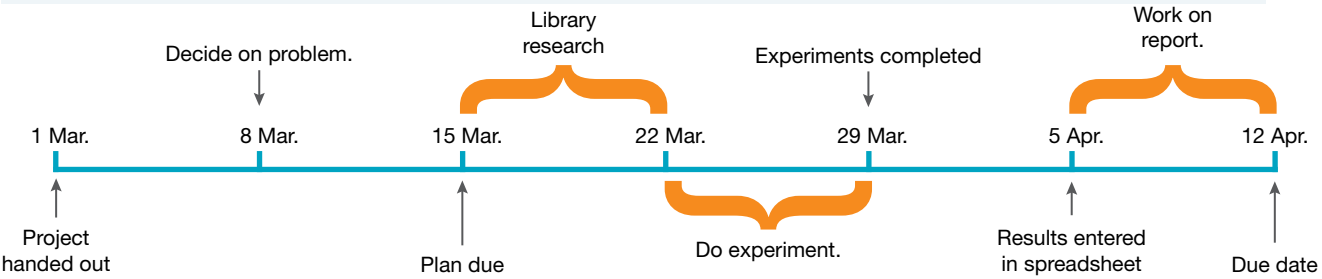
Diagrams can help us to organise our thinking and also to organise our time when planning a complex project. Storyboards, timelines, Gantt charts, cycle maps and flow charts are tools used to represent complex scientific processes, plan presentations and help you manage your time as you work on your SRP.

When you are set a large complex task such as your SRP, it is important to plan how you will use the time you have available. Leaving all the work until the last few days before the due date is unlikely to result in a high-quality project report. Depending on the problem you have chosen to investigate, you might need to allow time for plants to grow or for results to be collected over a period of time. Writing the final report, taking photographs and constructing tables and graphs of your results also take time. Before you start on your project, you should think about all the tasks required and construct a timeline or Gantt chart that shows when you need to have completed each task. This will help you complete your project on time without having to rush any part of the project.

Constructing a timeline

1. Draw a line to represent the total amount of time available; for example, if you have 6 weeks to work on your project, you might draw a 12 cm line.
2. Divide the line evenly to represent blocks of time; for example, 2 cm might represent 1 week.
3. Indicate on the timeline when you plan to have completed particular tasks.

A student's SRP timeline



Constructing a Gantt chart

A Gantt chart is another way of planning your time. It can show more clearly that some tasks will be done over an extended period of time. If you have access to a computer, a Gantt chart can be drawn easily using Microsoft Excel or another spreadsheet program.

1. Draw a table with each column representing a particular block of time, such as a week.
2. List the tasks to be completed in the first column of the table. Each task should take up one row of the table.
3. Shade the cells of the table that represent the time when you plan to work on that particular task.

An example of a Gantt chart for a student SRP is shown above.

Spreadsheet software can be used to draw Gantt charts.

	A	B	C	D	E	F	G	H
1	Task	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	
2	Decide on problem to investigate.							
3	Write aim and hypothesis.							
4	Design method.							
5	Do experiment and collect results.							
6	Write method.							
7	Construct tables and graphs of results using Excel.							
8	Write conclusion and discussion.							
9	Edit and proofread report.							
10								

17.4.2 Using storyboards to plan your work

A storyboard is similar to a comic strip. It is a series of diagrams that might be used to plan a PowerPoint presentation, movie or project. If you are planning a movie, each diagram might represent an outline of a scene in the movie. For a PowerPoint presentation, each diagram could represent one slide of the presentation. Your teacher might give you the option of presenting your SRP to your class using a short movie or PowerPoint presentation. A storyboard would be an excellent tool to plan such a presentation.

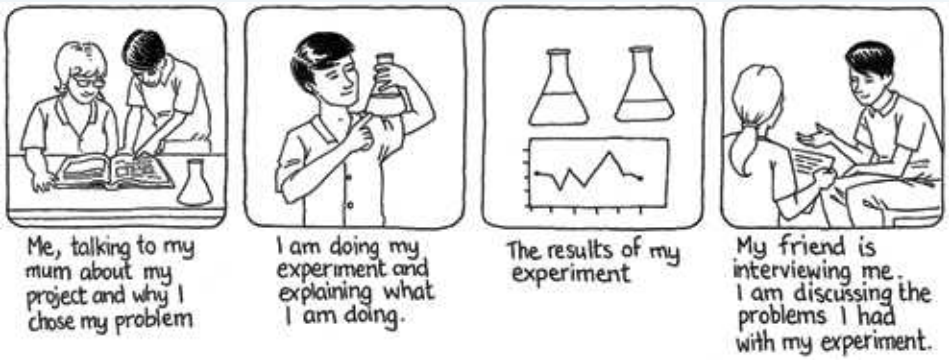
General plan for a storyboard

A Outline of scene 1	**B** Outline of scene 2
C Outline of scene 3	**D** Outline of scene 4
E Outline of scene 5	**F** Outline of scene 6

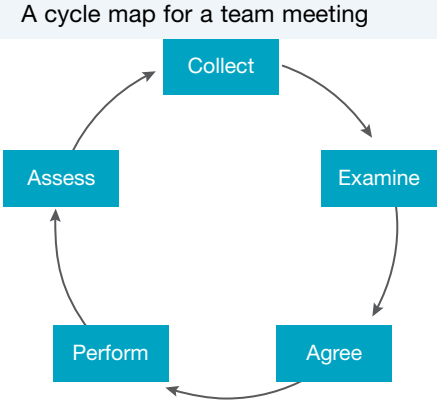
17.4.3 Going with the flow: flow charts and cycle maps

Flow charts and cycle maps are representations of particular processes. The method for an experiment can usually be represented by a flow chart. A cycle map is similar to a flow chart, but it forms a closed circle so it is useful to represent processes that repeat themselves, such as the water cycle or the life cycle of an organism. To draw a flow chart or cycle map, write each step or event and link them with arrows.

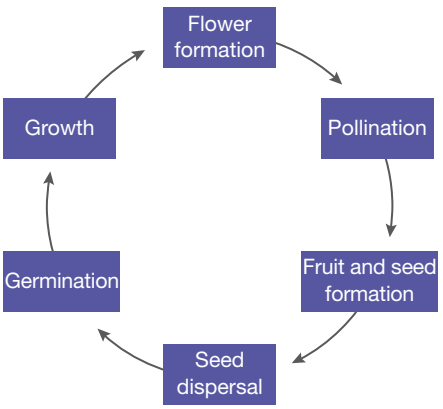
Storyboard for a movie presentation of a student SRP



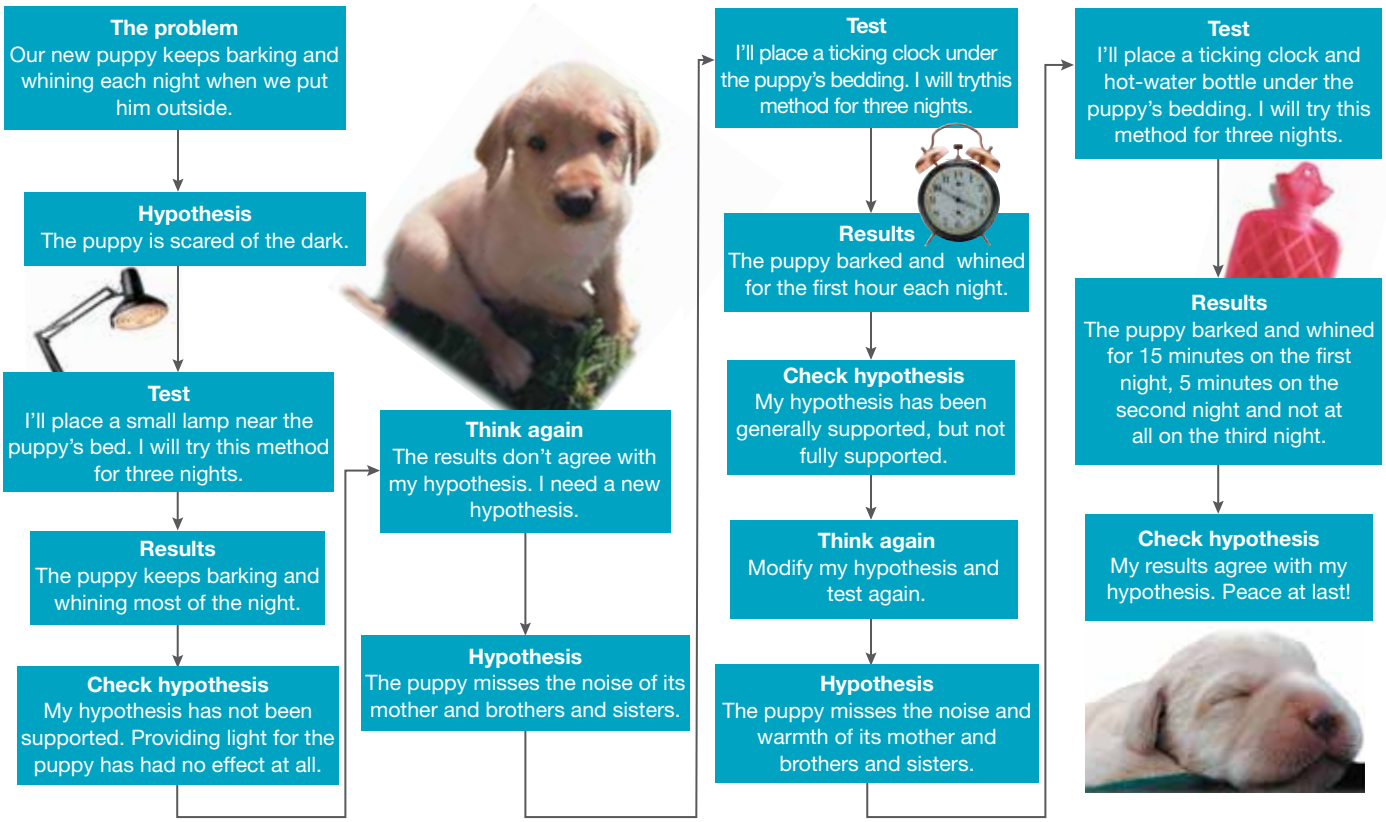
A cycle map for a team meeting



A cycle map showing the life cycle of a flowering plant



A flow chart of the process used to stop a puppy barking at night



17.4 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. **Recall** two similarities and two differences between a timeline and a Gantt chart.
2. **Identify** a visual tool that looks like a cartoon strip.
3. **Compare** cycle maps with flow charts.

Think

4. **Interpret** the flow chart above to answer the following questions.
   (a) What was the problem to be solved?
   (b) What action was taken when the first and second hypotheses were not supported?
   (c) Which variable was used in each of the three experiments?
   (d) Do you think each experiment was a fair test? **Explain**.
   (e) What other explanations could there be for the change in the behaviour of the puppy in the final experiment?
5. **Identify** the visual tool that you would use to show each of the following.
   (a) When various groups of animals first appeared on Earth
   (b) The procedure used to extract DNA from cells
   (c) The life cycle of a butterfly
   (d) The date on which each of your assignments is due this term
   (e) An outline of the video you would like to make for your cousin's sixteenth birthday
6. **Construct** a timeline that shows some of the key events that have occurred in your life so far.

7. **Construct** a Gantt chart that shows which subject you plan to work on each night of this week.
8. **Construct** a cycle map for the water cycle (*Hint:* See page 574.)
9. **Construct** a flow chart that shows how to make slime using the following recipe.
   Combine 20 mL PVA glue, 20 mL water and 3 drops of food colouring and stir. Prepare a saturated solution of borax. Use a syringe to measure 20 mL borax solution and add it to the glue mixture. Stir vigorously until the slime forms. Rinse the slime with water before playing with it.



17.5 Research and record keeping

17.5.1 What is a logbook?

Scientists do experiments to test hypotheses, which are based on observations as well as knowledge previously discovered by other scientists. An important part of the job of scientists is to read reports written by other scientists and to do background research before designing their experiments. Scientists also need to keep records of all their observations and any changes they make to the design of their experiments. When you do a student research project, you will probably be asked to do this by keeping a logbook.

A logbook is a document where you keep a record of all the work you do towards a project. Each entry should be dated like a diary. In your logbook, you might include the following items.

- A timeline or other evidence of planning your use of time
- Notes about conversations you have had with teachers, friends, parents or experts on your project and how these conversations affected your project. Make sure you record each person's details so you can acknowledge their contribution in your report.
- Notes from library research you have done for your project. Include all the details you will need for your bibliography.
- A plan or rough outline of the method you will use for your experiment(s)
- Notes about any problems you encountered during your project and how you dealt with these
- Information on any changes you made to your original plan
- Results of all your experiments (these may be presented roughly at this stage)
- A plan or storyboard for your presentation if you are required to present your research to your class

A logbook can be written by hand on paper, it can be done with a wordprocessing program on a computer or even be in the form of a website. A blog is a website that has dated entries so it can be used as a logbook. It has the added advantage that you can invite other people, such as your friends, parents and teachers, to look at your work and post comments. You should check with your teacher on the format required for your logbook.

Screenshot of a blog site used to report on an investigation



17.5.2 Researching your topic

Before embarking on your science investigation you will need to do some background research. You need to find out:

- background information about the topic you are investigating. Let's say you are planning an investigation to test whether plants grow faster

when illuminated with green light or red light. This would require you to do some research about photosynthesis and the normal requirements of plants. Designing an experiment to test the effectiveness of various detergents would involve research about detergents and how they work.

- method ideas. Science textbooks are a great source of ideas when designing your method. There are also websites where student research projects carried out by other students have been published. These can also be a source of inspiration. You should never just copy the method used by another student or published in a textbook, but the work of other people can be a good starting point to get you thinking about the best way to carry out your experiment. Scientists spend a great deal of time reading science journals where scientists publish reports of their investigations. Building on the research of other scientists is a great way to keep science moving forward.
- safety information. If your experiment involves chemicals or any materials you are not familiar with, it is important to research the potential risks associated with these.

17.5.3 Beyond Google

When your teacher asks you to research a topic, do you find yourself going straight to a search engine such as Google or Bing and typing in the topic in the search box? The amount of information on any given topic that can be easily accessed via the internet is bewildering, but searching for a particular piece of information often requires more than a Google search. To save time and ensure you access quality information, try the following alternative sources of information.

Non-fiction books

Non-fiction books, including high-school science textbooks are a great source of ideas for research projects. Books written for high-school students often use simpler language and are easier to understand. High-school science textbooks contain background information on a wide range of topics and many include methods for experiments that could be modified to investigate different problems. Non-fiction books are often written by people with expertise in the area and the information is checked by other people before the book is published; this is important when assessing the reliability of the information.

Library catalogue

Your school library and local library each has a library catalogue. This is a database that allows you to search for resources relating to a particular topic. It brings up resources in a variety of formats including websites, movies and books. Using the right search words is important. If you were looking for information about the effect of green and red light, you could do a search using the term ‘photosynthesis’, but the terms ‘plant’ and ‘colour’ might also produce useful information.

Journals and science magazines

Scientists publish their research in scientific journals, so they are a great place to read about experiments carried out by scientists; however, since journals are read mainly by scientists, they can be difficult to understand. Science magazines report on the latest scientific achievements using simpler language. The CSIRO publishes two magazines aimed specifically at school students. Your school library probably has copies of these and other popular science magazines. Some science magazines also have a website that makes it easier to search for articles on a particular topic.

Refine your search

To save time, think carefully about the search words you use. Try different search engines. Some search engines are specific to particular subjects. Use the advanced search features or the scholar version of a search engine. All of these strategies might save you a great deal of time when looking for specific information.

17.5.4 Is it reliable?

Most research is now carried out over the internet, but a great deal of information on the internet is unreliable. Reliable information is information that can be trusted. Imagine that your friend emailed you a link to a website that said that brushing your teeth with peppermint-flavoured toothpaste causes your tongue to turn green over time. How could you check that the information was reliable?

- Check the URL. Each web page has a URL (uniform resource locator). This is the address you type in to access the page. The ending of the URL can be useful for assessing the reliability of a web page. A URL with an .edu ending is usually from an educational institution such as a school or university. The ending .gov is used for government websites while an .org ending usually indicates that the web page is associated with a non-profit organisation.
- Look for information about the author of the web page, the organisation associated with the web page and the date on which the information was last updated. A web page that provides no such information is less likely to be reliable. If an author's name is provided, what are their qualifications? Do they have expertise in the area they are commenting on? Are they likely to show bias? For websites associated with an organisation, is the organisation likely to benefit from a particular viewpoint about an issue?
- Check the information against other sources. Experimental results are considered reliable if the experiment, when repeated a number of times, consistently produces similar results. Similarly, the reliability of information from secondary sources can be assessed by checking it against other sources.

Where did your information come from?

Your teacher will probably ask you to submit a bibliography for your student research project. This is a list of all the resources you used. There are a variety of formats and you should check with your teacher which format is used at your school. To ensure that you can complete your bibliography, you should note all the details of the sources from which you obtained information in your logbook.

Use a variety of information sources when looking for background information for your project.



17.5 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** why a logbook is a bit like a diary.
2. **Define** the following terms: blog, science journal, search engine, URL.
3. List three ways of assessing the reliability of the information on a web page.

Think

4. Imagine you are scientist. **Assess** the advantages and disadvantages of maintaining a blog rather than keeping a logbook in your office.

5. You can find information about science topics in science textbooks and on the internet.
   (a) **Explain** why you would not find the results of scientific research that was done last month in a printed science textbook.
   (b) **Outline** some advantages of using science textbooks as a source of information.
6. **Explain** why it is important for scientists to read about the research carried out by other scientists in science journals.

Research

7. Type one of the questions below into a search engine of your choice (or type in your own appropriate question instead). **Assess** the reliability of the first three links displayed by the search engine and **outline** how you might find better information on these topics.
   (a) Is food colouring safe?
   (b) Do mobile phones cause brain cancer?
8. Use the **Wikipedia** weblink in the Resources tab to answer the following questions about Wikipedia, an online encyclopaedia.
   (a) When did Wikipedia start?
   (b) Who founded Wikipedia?
   (c) How is Wikipedia different from other online encyclopaedias such as World Book Online and Encarta Online?
   (d) Why is it particularly important to check the reliability of information found on Wikipedia by comparing it with information from other sources?
   (e) **Outline** some reasons why people may wish to put inaccurate information on Wikipedia.
   (f) Which Wikipedia entries are most likely to be highly reliable: those that have been edited many times by a large number of people or those that have been written by only one person and never edited. **Explain** your answer.

learnON RESOURCES — ONLINE ONLY

Explore more with this weblink: Wikipedia

17.6 Designing your method

17.6.1 Experiments

Your student research project will include one or more experiments. Each experiment must be carefully planned to ensure that the results are valid, reliable, precise and accurate. Designing a scientific investigation usually begins by considering the variables involved in the experiment. You should also think about the observations and measurements that you will need to make. Most importantly, your experiment must be safe and minimise risk to yourself and others.

Variables

Variables are the conditions that can be changed in an experiment. In topic 1 (see page 30), you learned that there are different types of variables in experiments. The example below will help you revise this.

Problem: Do black cars heat up in the sun faster than white cars?

Type of variable	Definition	Example
Independent	The variable that is deliberately changed in the experiment	Colour of car
Dependent	The variable that is measured in the experiment	Temperature
Controlled	Variable that must be kept constant to ensure that the experiment is fair	• Location of car (both cars in full sun) • Outside temperature • Type of car • Window tinting • Location of thermometer in car

Which car will heat up faster on a hot day?



17.6.2 Valid experiments

A valid experiment tests what it is designed to test. For example, if you want to measure a student's intelligence, getting the student to complete an IQ test would be a more valid test of her intelligence than measuring how high she can jump. Imagine that a student wants to find out if washing powder X cleans better than washing powder Y. A valid test might involve staining two pieces of the same type of fabric with the same amount of engine oil and washing these in the same way. After washing, the amount of grease left on each piece of fabric could be compared. On the other hand, asking people to compare the smell of the two washing powders would not be a valid way of testing which powder washes clothes better. Using washing powder X to wash cotton stained with tomato sauce and using washing powder Y to wash wool stained with engine grease would not be a valid test either.

The most important feature of a valid experiment is to change only the independent variable. The independent variable is the condition that is being tested. In the example above, the independent variable is the type of washing powder. The other variables should be controlled (kept the same) as far as possible.

In many instances, a control is needed for an experiment to be valid. A control allows the scientists to compare the results with and without changing the variable. For example, if you want to test whether a fertiliser makes a plant grow faster, you would need to grow two plants under identical conditions and apply the fertiliser to only one of the plants. By comparing how quickly both plants grew, you could decide whether the fertiliser has an effect.

17.6.3 The placebo effect

When scientists test the effectiveness of medicines and other medical treatments, they need to take into account the placebo effect. A placebo looks and tastes identical to the real medicine but does not contain any of the active ingredients found in the medicine, so it should not have an effect on patients. Many studies have shown that patients given a placebo report improvements in their condition. To allow for the placebo effect, scientists usually test new drugs by giving half of the patients the real medicine and the other half (the control group) a placebo. The patients are usually not told whether they are taking the placebo or the real medicine. This is called a blind study. In addition, in a double-blind study, the nurses and doctors who deal with the

Do the tablets really work or is it a placebo effect?



patients and collect the results do not know which patients are receiving the placebo either. This ensures that they do not treat the patients receiving the placebo differently or prompt them when asking about their symptoms.

17.6.4 Precise measurements

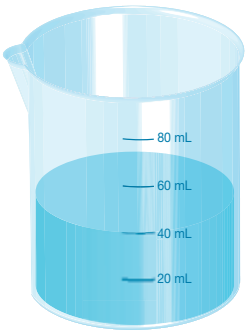
The degree of precision of the measurements taken in an experiment depends on the instruments that have been used. If you want to measure the length of your classroom, you could also use a trundle wheel with marks every 10 cm, or you could use a tape measure marked in millimetres. The tape measure would provide the most precise measurement. Similarly, to measure 100 mL water, you could use a measuring cylinder that is graduated in millilitres or you could use a measuring cup that is marked every 100 mL. The measuring cylinder would provide a more precise measurement than the cup. A set of scales that measures mass to 2 decimal places is more precise than one that measures mass to 1 decimal place.

17.6.5 Accurate results

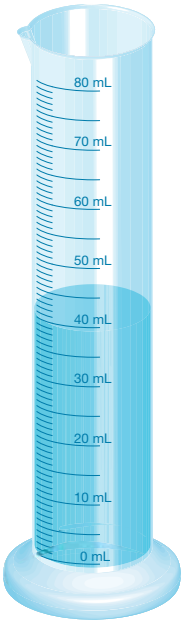
Accurate results are not only precise but also correct. A small measuring cylinder can provide a reasonably precise measurement of a volume of water but, if it is not read at eye level, the measurement may not be accurate. A set of bathroom scales might display a reading with 2 decimal places but, if you use it on carpeted floor, it may not provide an accurate measurement of your mass if it is designed to be used on a hard floor. To ensure that your results are accurate you should use measuring instruments correctly and in some instances it may be necessary to calibrate the instruments. To calibrate a set of scales, for example, you could place an object that has a mass of exactly 100 g on the scale and adjust the scale until it reads exactly 100 g. A poorly designed method can also affect the accuracy of the results, particularly if variables have not been properly controlled.

Which piece of equipment provides the most precise measurement?

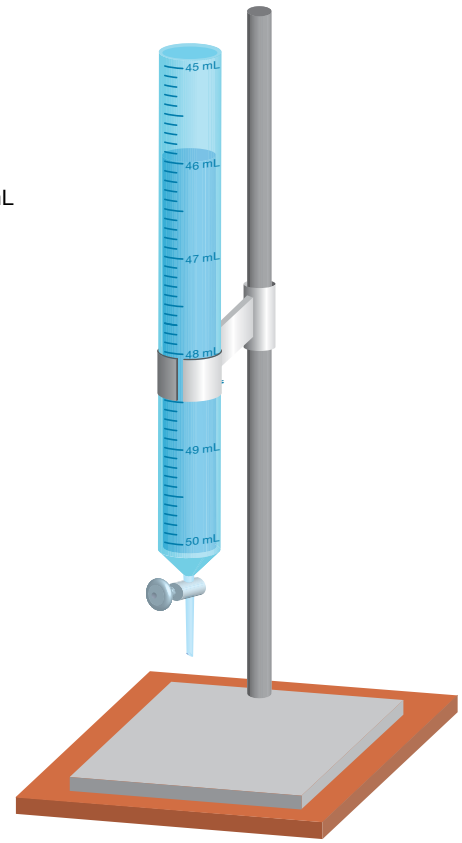
Beaker
Each graduation = 20 mL



Measuring cylinder:
Each fine graduation = 1 mL



Burette
Each fine graduation = 0.1 mL



Reliable experiments

An experiment is reliable if it consistently produces the same results when it is repeated. Imagine that you want to compare the strength of plastic bags by filling the bags with weights until the bag breaks. If the experiment is reliable, you will find that the mass needed to break a particular type of bag would always be about the same each time the experiment was repeated. If the results vary greatly between trials, the experiment is not reliable. You can improve the reliability of an experiment by repeating it a number of times, checking for consistency and using the average of the results to draw conclusions.

Experiments can be repeated in different ways. In some instances, it is just a matter of doing the same experiment again. In *Investigation 17.2*, you compared the speed of a balloon rocket gliding along different types of string. To ensure the reliability of the results you could do the experiment a few times, check for consistency and then calculate and compare the average speeds. Each repetition of an experiment is called a **trial**. Increasing the number of trials generally increases the reliability of the experiment. For experiments involving plants, animals and people, it is usually easier to do the experiment once but use a large number of plants, animals or people. The number of organisms used in the experiment is called the sample size. A large sample size is a feature of well-designed experiments.

17.6.6 Keep it safe

The most important thing to consider when planning an investigation is safety. Your teacher may ask you to write a risk assessment before you start your research project. A risk assessment involves listing any potential hazards relating to your investigation and explaining how you will minimise these risks. For example, if you were doing an experiment to test whether the temperature of an acid affects how quickly it reacts with magnesium, your risk assessment might look like the table below.

Risk	How the risk will be minimised
Acid splashing into face and eyes	• Wear safety goggles. • Heat acid using a water bath rather than directly over a Bunsen burner flame. • Use dilute acid rather than concentrated acid. 
Cutting fingers when tearing small pieces of magnesium	• Use scissors to cut magnesium.

INVESTIGATION 17.3

The flying straw

AIM: To assess variables that affect how far a straw flies

You will need:

paper
scissors
straws
sticky tape
metre ruler or tape measure
stopwatch

- Cut out two strips of paper. One strip should be 10 cm by 2 cm and the other should be 20 cm by 2 cm.
- Attach the strips of paper to a straw as shown in the photo at right.
- Throw the straw forwards and observe how far it flies. This is the basic flying straw.

A flying straw



Discussion

1. The length of the straw is one variable that may affect how far the flying straw can fly. List at least five other variables that may affect the distance flown.
2. Choose one of the variables from question 1 and design an experiment to test the effect of this variable. Decide what you will measure first. It could be the distance flown, the amount of time the straw stays in the air or whether the straw flies in a straight line. Your experiment should include:
   (a) the aim
   (b) a hypothesis

(c) the method, including a diagram
(d) a table to enter your results.
3. Carry out the experiment and enter the results in the table you designed.
4. Write a conclusion based on your results.

17.6.7 Surveys

Your student research project may involve gathering data using a survey. Some features of good surveys include:

- a large sample size. Many people should complete the survey.
- choosing your subjects carefully. If you carried out a survey to determine whether school students have a better awareness of the health effects of smoking than their parents, you would need to ensure that you surveyed both school students and parents. The survey would not be fair if you surveyed only school girls and fathers. You would need to survey both males and females for the two age groups. Similarly, the investigation would not be fair if you compared students from a very disadvantaged background with wealthy parents.
- keeping the questions short and easy to understand
- using an online survey to make collation of the results easier.

17.6 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 each of the following terms with its meaning: variable, dependent variable, independent variable, controlled variables, sample size, reliable, accurate, valid, trial, risk assessment.
   (a) Describes measurements that are precise and correct
   (b) The number of plants, animals or other items used in an experiment
   (c) The variables that must be kept constant in an experiment
   (d) Describes an experiment that measures what it is supposed to test
   (e) The variable that is deliberately changed in an experiment
   (f) Name given to each repetition of an experiment
   (g) Describes an experiment that produces similar results when it is repeated
   (h) A list of the hazards in an experiment and how these will be minimised
   (i) Something that can be changed in an experiment
   (j) The variable that is measured in an experiment

Think

2. Charlotte wanted to compare the amount of air in two brands of ice-cream. She placed a large spoon of each ice-cream in two different cups and let the ice-cream melt. She then measured how much liquid was in each cup. There was less liquid in cup B so she concluded that ice-cream B must contain more air.
   (a) **Describe** one way in which Charlotte could improve the validity of her experiment.
   (b) **Outline** how the precision of Charlotte's measurements could be increased.
   (c) **Outline** how the experiment could be made more reliable.

3. Copy and complete the following table.

Hypothesis	Independent variable	Dependent variable	Controlled variable
Plants grow faster when it is hot.	Temperature	Height of plant	Plant species, amount of water, soil type
Exercise increases breathing rate.			
Paper towel A is more absorbent than paper towel B.			
Sugar dissolves faster in hot water than in cold water.			
The more you water plants, the faster they grow.			

4. Jossie wanted to find out if the mass of a rock affects how far the rock can be thrown. She weighed some rocks, threw each rock as far as possible and measured the distance by pacing between the point where she threw the rock and the point where it landed.
   (a) **Construct** a table listing at least two risks associated with this experiment and how each risk could be minimised.
   (b) **Describe** how the experiment could be made more:
      (i) accurate
      (ii) reliable
      (iii) valid.

Design

5. Design experiments to test the following hypotheses.
   (a) Eggs become less dense as they age.
   (b) Detergent A produces more foam than detergent B.
   (c) Cola drink P contains more sugar than cola drink C.
   (d) Talking to plants makes them grow faster.
   (e) Chocolate S melts at a higher temperature than chocolate Q.
6. Design a survey to test the hypothesis that people born after 1995 are more likely to wear sunscreen and have better awareness of the health effects of overexposure to sunlight than those born before 1995.

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Complete this digital doc: Worksheet 17.2: Accuracy and reliability (doc-12497)

17.7 Presenting your results

17.7.1 Using tables and graphs

Values or measurements obtained from an investigation are called data. Having collected the data, it is important to present them clearly so that another person reading or studying the information can understand it. Tables and graphs are a great way to organise data.

A table organises data so that trends are more easily identified. An example of a simple table is shown on the following page; it includes all the features you need to remember when constructing a table.

Always include a title for your table.

Temperature of the Earth at different depths

The column headings show clearly what has been measured. Include the measurement units in the headings.

Depth (km)	Temperature (°C)
0	15
1	44
2	73
3	102
4	130
5	158
6	187
7	215
8	242

Use a ruler to draw lines for rows, columns and borders.

Enter the data in the body of the table. Do not include units in this part of the table.

You may need to construct more complex tables, like the one below, to present your student research project results.

Do large paper aeroplanes fly further than small paper aeroplanes?

Labels

Width of paper (cm)		21	15	9
Length of paper (cm)		14	10	6
Distance flown (m)	Trial 1	4.5	6.2	3.2
	Trial 2	4.9	5.9	3.6
	Trial 3	4.6	5.8	3.5
	Average			

Units

Using graphs

Why use graphs?

Organising data as a graph is a widely recognised way of making a clear presentation. It makes the information easier to read, interpret, show trends and make conclusions.

A graph, especially a line graph, can also be used to find values other than those used in the investigation. This can be done by interpolation or extrapolation (see Using a line graph for interpolation on page 704).

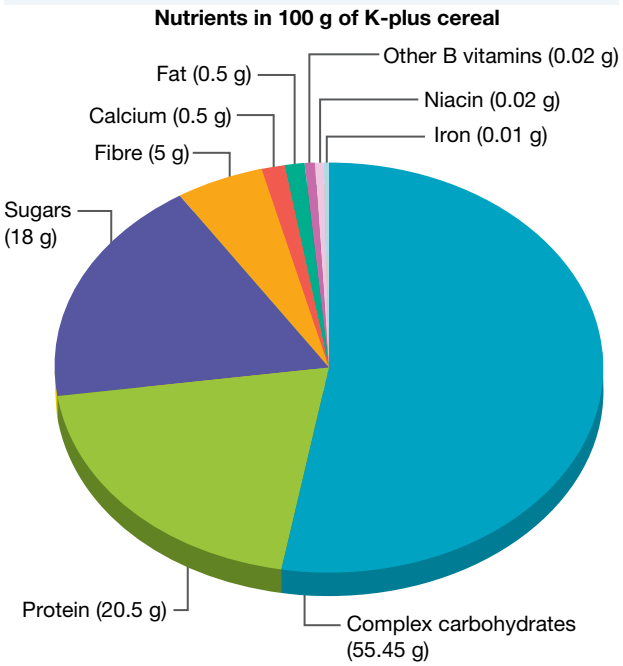
Types of graphs

There are five different types of graphs: pie charts; column graphs and bar graphs; divided bar graphs; histograms; and line graphs.

17.7.2 Pie charts (or sector graphs)

A **pie chart** (also known as a **sector graph**) is a circle divided into sections that represent parts of the whole. This type of graph can be used when the data can be added as parts of a whole. The example at right shows the nutrients, vitamins and minerals found in a type of breakfast cereal.

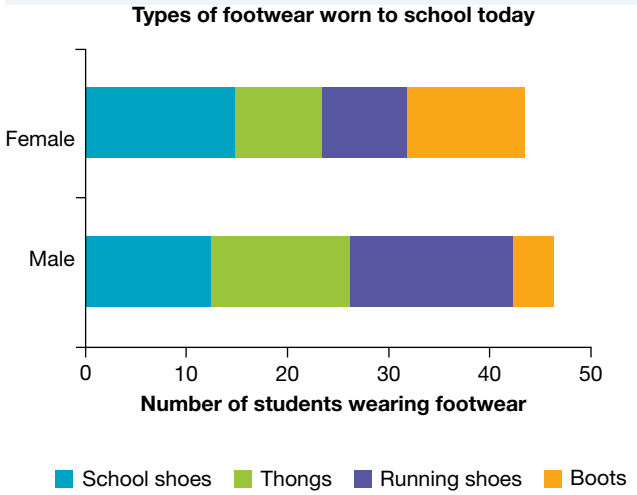
A pie chart



17.7.3 Divided bar graphs

Divided bar graphs are also used to represent to represent parts of a whole. However, the data are represented as a long rectangle, rather than a circle, divided into sections. The example below shows the type of footwear worn to school today by male and female students.

A divided bar graph

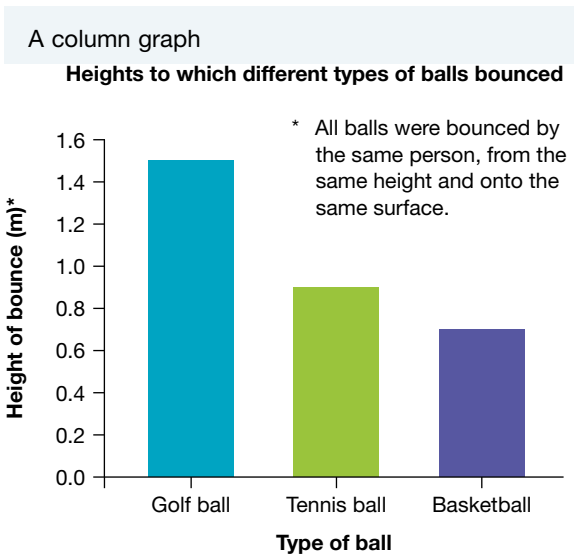


17.7.4 Column graphs and bar graphs

A **column graph** (sometimes called a **bar graph**) has two axes and uses rectangles (columns or bars) to represent each piece of data. The height or length of the rectangles represents the values in the data. The width of the rectangles is kept constant. This type of graph can be used when the data cannot be connected and are therefore not continuous.

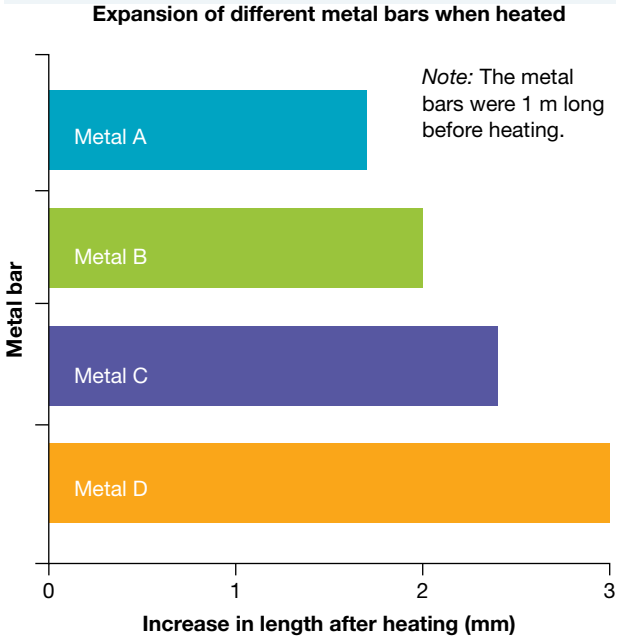
The example below shows data on the average height to which different balls bounced during an experiment. Each column represents a different type of ball.

A column graph



The following example shows the amount by which different metal bars expanded when heated. Each bar represents a different metal bar.

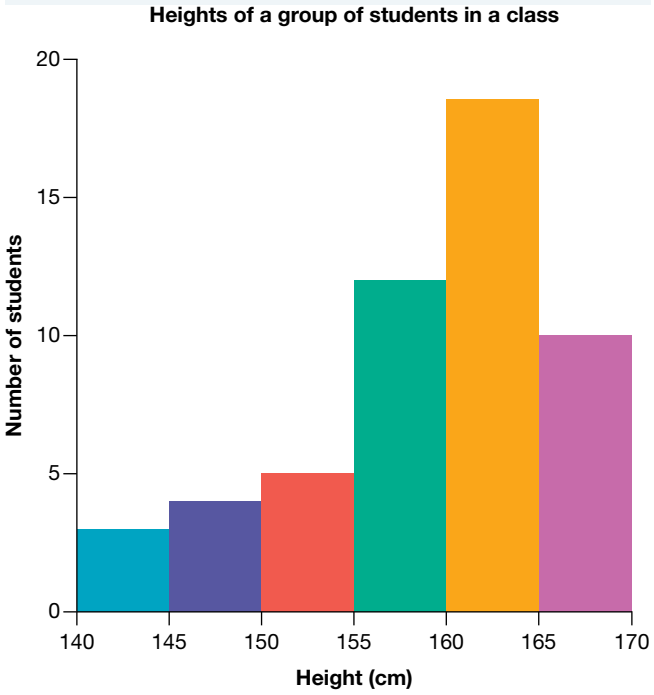
A bar graph



17.7.5 Histograms

Histograms are similar to column graphs except that the columns touch each other because the data are continuous. They are often used to present the results of surveys. In the histogram below, each column represents the number of students who reached a particular height.

A histogram



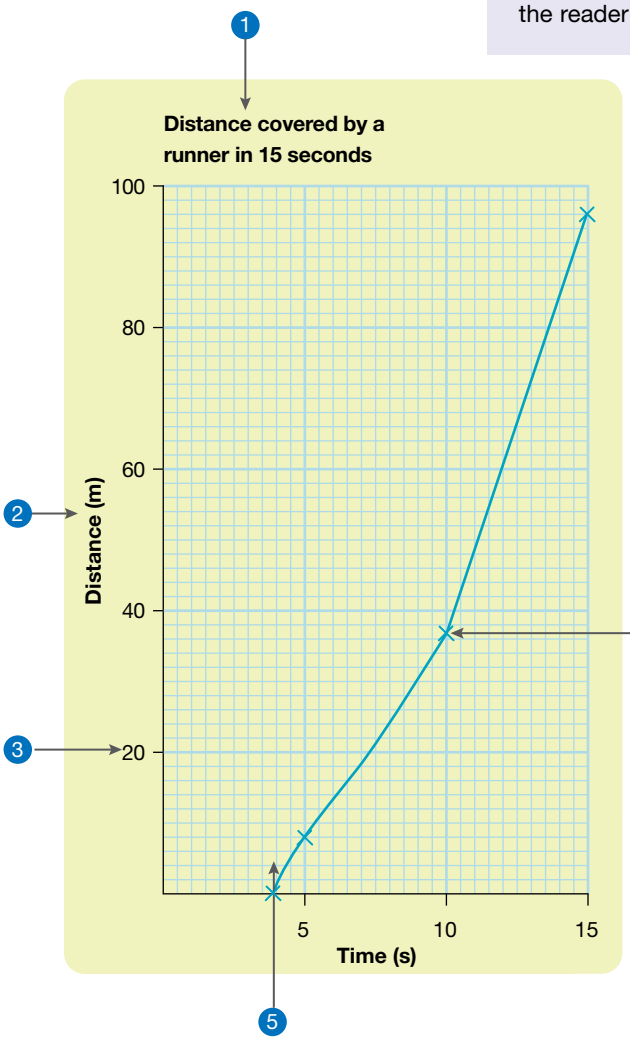
17.7.6 Line graphs

A **line graph** has two axes — a horizontal axis and a vertical axis. The horizontal axis is known as the ***x*-axis**, and the vertical axis is known as the ***y*-axis**. The line graph is formed by joining a series of points or drawing a line of best fit through the points. Each point represents a set of data for two variables, such

as height and time. Two or more lines may be drawn on the same graph. Line graphs are used to show continuous data — that is, data in which the values follow on from each other. The features of line graphs are shown below.

1. Title
Choose a sensible title that tells the reader what the graph is about.

2. Label the axes
The independent variable (the variable that was changed deliberately) goes on the *x*-axis. The dependent variable (the variable that is measured) goes on the *y*-axis.
Most quantities have units. These should be shown in parentheses after the axis label.



Data table

Distance (m)	Time (s)
0	4
8	5
37	10
96	15

3. Choosing an appropriate scale
Look at the largest *x* and *y* values that need to be plotted and choose a scale that will allow you to fit these values on the graph.
In this case, the largest *y* value is 96 and the grid has five large squares. Making each large square worth 20 means that 96 will fit on the graph.
Along the *x*-axis, the largest value that needs to be plotted is 15. There are three large squares so making each large square worth 5 allows the data to fit.
Try to fill most of the space available.
Ensure that the scale is uniform. Each division on the scale should be worth the same.

4. Plotting the points
Plot the points as accurately as possible.

5. Drawing the line
In many instances, a line of best fit is the most appropriate way of representing the relationship between two variables. A line of best fit can be a straight line or a curve. For a straight line of best fit, use a ruler to draw a line that goes through as many points as possible and has about the same number of points above and below the line. For a curved line of best fit, use the same procedure but draw the line freehand. Software such as Excel use calculations to add a line of best fit to a graph.

17.7.7 Interpolation

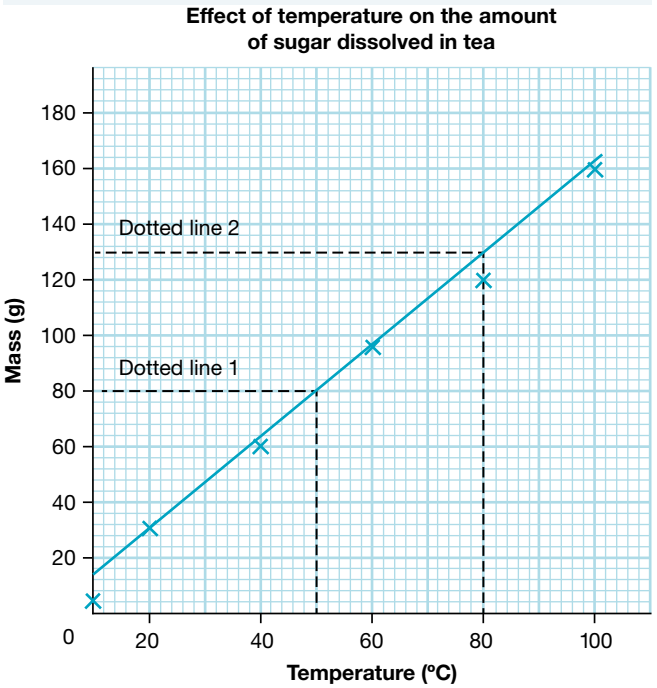
Line graphs can be used to estimate measurements that were not actually in an experiment. The table below shows the results of an experiment where a student measured how many spoons of sugar dissolved in a cup of tea at various temperatures.

The student did not measure how much sugar dissolved at 50 °C, but we can work this out by **interpolation**. First we need to plot the data collected in the experiment. Then we read off the graph the amount of sugar that would dissolve at 50 °C. The same procedure can be used to work out the water temperature that would be needed to dissolve 130 g sugar in one cup of tea. This is shown in the graph below.

Amount of sugar that dissolves in one cup of tea at different temperatures

Temperature (°C)	Mass of sugar dissolved (g)
0	4
20	30
40	60
60	98
80	120
100	160

Using a line graph for interpolation



17.7.8 Extrapolation

In many cases it is also possible to assume that the two variables will hold the same relationship beyond the values that have been plotted. This is called **extrapolation**. Consider the following table, which shows the results obtained when different masses were attached to a spring and the increase in length of the spring was measured.

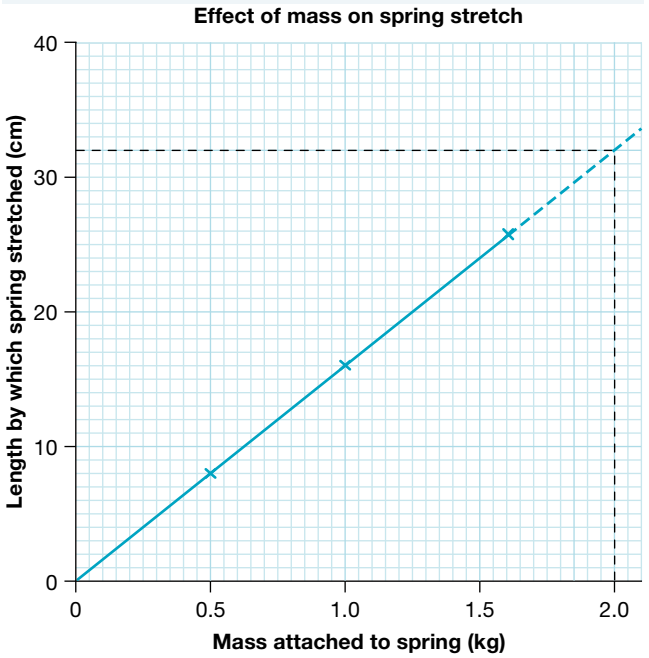
If you want to predict the mass needed to stretch the spring by 32 centimetres, you need to plot the data on a graph and extrapolate the value.

The data in the following table have been plotted on the following graph. Values have been plotted up to a mass of 1.6 kg and an increase in length of of 26 centimetres. The line on the graph has been projected onwards (as the dotted lines show). This extrapolation shows that a mass of 2 kg will stretch the spring 32 centimetres.

Amount that a spring stretched when various masses were attached to it

Mass attached to the spring (kg)	Length by which spring stretched (cm)
0	0
0.5	8
1.0	16
1.6	26
?	32

Using a line graph for extrapolation



17.7 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.

Analyse and evaluate

1. (a) **Construct** a line graph for the data shown in table.
   (b) Use your graph to interpolate the temperature at a depth of:
   (i) 4.5 km
   (ii) 7.5 km.
2. (a) Complete the bottom row of the table.
   (b) **Construct** a column graph showing the length of the paper used to make the plane on the horizontal axis and the average distance flown on the vertical axis.
3. **Construct** a column graph using the information below.

Nutrients in 30 g serving of ice-cream

Nutrient	Amount (g)
Protein	2.00
Fat	6.00
Carbohydrate — polysaccharide	11.00
Carbohydrate — sugars	10.00
Cholesterol	0.02
Calcium	0.10
Potassium	0.80
Sodium	0.05

4. The following table shows the uses of plastics in Australia.
   (a) Select a suitable graph type and prepare a graph from this table.

Uses of plastics in Australia

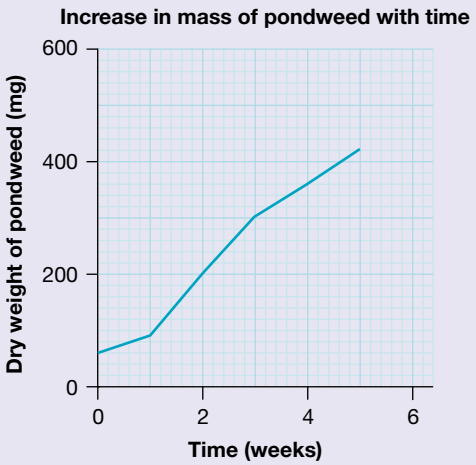
Use	Percentage (%)
Agriculture	4.0
Building	24.0
Electrical/electronic	8.0
Furniture and bedding	8.0
Housewares	4.0
Marine, toys and leisure	2.0
Packaging and materials handling	31.0
Transport	5.0
Others	14.0

   (b) Choose two uses of plastic from your graph. For each use, state a particular item that is made of plastic.
   (c) There has been recent controversy about the waste products that humans create.
      (i) Can you suggest any uses of plastics that would contribute to waste products? List them and explain your choices.
      (ii) Can you suggest alternatives to reduce the amount of plastic waste products?
5. The data in the following table relate the speed of a car to its stopping distance (the distance the car travels after the brakes are applied).

Relationship between the speed of a car and its stopping distance

Speed of car (m/s)	Stopping distance (m)
0	0
10	12
20	36
30	72
40	120

   (a) **Construct** a graph of the data.
   (b) Make a conclusion about the information in the graph.
   (c) How could this information be applied to your everyday life?
6. The following graph shows the increase in mass of pondweed (a type of plant that grows in ponds).
   (a) What was the mass of the pondweed after 312 weeks of growth?
   (b) How long did it take for the pondweed to reach a mass of 250 grams?
   (c) **Predict** the mass of pondweed after 6 weeks of growth.
   (d) Can you be sure that your extrapolation in part (c) is valid? **Justify** your answer.
   (e) Would the interpolations in parts (a) and (b) be more valid than your extrapolation? Discuss your ideas in class.



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Complete this digital doc: Worksheet 17.3: Presenting results (doc-12498)

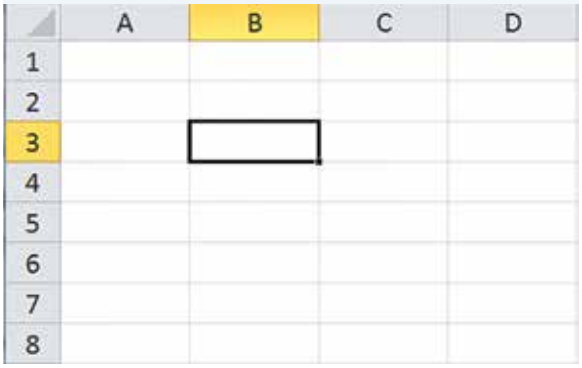
17.8 Using technology: spreadsheets

17.8.1 Some spreadsheet terminology

A spreadsheet is a document that stores data in columns and rows. Spreadsheets used to be written on paper by hand. Shopkeepers and bank tellers needed to keep neat handwritten ledgers to record all transactions. Today, computers and software such as Microsoft Excel are used to create and edit spreadsheets. Spreadsheets can also be used to create graphs and charts at the click of a button.

In a spreadsheet, the data are organised in rows and columns. The columns are named using letters (such as column A) and the rows are named using numbers (such as row 3). Cells are the boxes in the spreadsheet. The cell reference tells us which column and row the cell is in. For example, cell B3 is in column B and row 3. The active cell is the cell you will type the data in. In Excel, it has a dark border around it. This is shown in the diagram at right.

Cell B3 is the active cell.



Working with spreadsheets on a computer

When you create a spreadsheet, you need to decide how many columns and rows you will need and enter a suitable heading for each column. This is similar to designing a table. Make sure that you include units where relevant.

17.8.2 Using formulae in a spreadsheet

If you want to do calculations on the data in a spreadsheet, you need to enter a formula. In most spreadsheet programs, a formula starts with an equals sign (=). If you want the total of cell A2 and cell B2 to appear in cell C2, you would type the formula '=A2+B2' in cell C2, and then press the *Enter* key. Most spreadsheet packages have a set of functions that can be used as a shortcut to typing a formula. For example, it is much quicker to use the Average function to calculate the average of 50 numbers than to type in a formula that adds up the 50 cells and divides the total by 50.

Drawing graphs and charts

The procedure for drawing graphs varies slightly for different software packages. In Excel you can create graphs by selecting the data, then clicking on *Insert* and the type of graph you want to produce. Once the graph has been created use the *Layout* tab to add axis labels and a title for your graph.

INVESTIGATION 17.4

Dissolving aspirin

AIM: To investigate the effect of temperature on dissolving time

You will need:

beaker
thermometer
ice
Bunsen burner, tripod, heatproof mat
2 effervescent tablets, such as Aspro
stopwatch

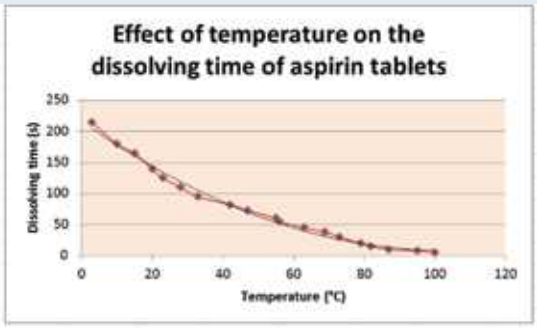
- Your teacher will assign each group two temperatures to test. For example, your teacher might ask you to test 20 °C and 50 °C.
- Pour 200 mL water into a beaker. Adjust the temperature of the water by adding ice or by heating the water over a Bunsen burner until the water temperature matches one of the temperatures you are to test.
- Add one of the tablets to the water. Use the stopwatch to record the time taken for the tablet to dissolve completely.
- Repeat these two steps for the second temperature.

Use the following instructions to plot your data using spreadsheet software.

Note: The following instructions assume that you are using Excel 2010. If you are using a different spreadsheet package, you may need to modify some of the steps accordingly.

- Create a spreadsheet with the column headings 'Temperature (°C)' and 'Time taken to dissolve (s)'.
- Enter all the groups' results in your spreadsheet.
- If necessary put the results in order from the lowest to the highest temperature by selecting (highlighting) all the data and using the *Sort* function. You should end up with a table similar to the one at right.
- With the data selected, click on the Insert tab, then on *X Y (Scatter)*, and choose the option where the points are joined by a smooth line. A graph similar to the one at right should appear. You can then add axis labels and a title by clicking on the *Layout* tab. The axis titles and chart title icons are displayed in the ribbon.

	A	B
1	Temperature (°C)	Time taken to dissolve (s)
2	3	215
3	10	180
4	15	165
5	20	139
6	23	125
7	28	110
8	33	95
9	42	82
10	47	73
11	55	60
12	56	55
13	63	45
14	69	38
15	73	30
16	79	20
17	82	15
18	87	10
19	95	8
20	100	5

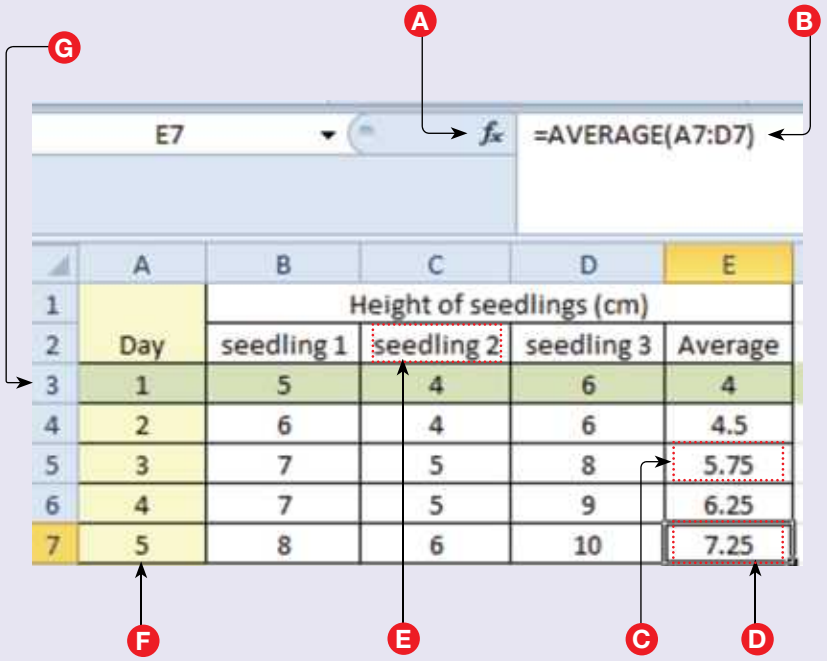


17.8 Exercise: Remember and think

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 the screenshot at right, identify the letter pointing to:
   (a) cell C2
   (b) cell E5
   (c) the active cell
   (d) a formula
   (e) the *Insert Function* button
   (f) a column
   (g) a row.
2. List two advantages and two disadvantages of using a computer spreadsheet program to store data rather than keeping handwritten records in a book.



Create

3. (a) Collect the following data for each student in your class.
   (i) First name
   (ii) Gender
   (iii) Foot length (cm)

(iv) Height (cm)
(v) Favourite subject
(vi) Country where their mother was born

(b) Enter the data you collected into a spreadsheet.
(c) **Construct** an *X Y (Scatter)* graph (without joining the points) showing foot length on the *x*-axis and height on the *y*-axis.
(d) Use your graph to decide if there is a relationship between foot length and height.
(e) Apply a filter to the 'Gender' column. If you are using Excel 2010, you can do this by selecting the column and then clicking the *Sort & Filter* icon.



(f) Select the *Filter* option. A drop-down arrow should appear near the column heading. Clicking on this drop-down arrow displays options that allow you to display just the males, just the females or both.
(g) **Construct** an *X Y (Scatter)* graph of height versus foot length for only the girls in the class. Is the graph different from the graph you produced in part (c)? In what ways?
(h) Look at the 'Favourite subject' column and count how many students liked each subject most. Create a new spreadsheet with the column headings 'Favourite subject' and 'Number of students'.
(i) Create a column graph and a pie chart to represent the data in the table you constructed in part (g).
(j) Repeat steps (g) and (h) for the data in the 'Country' column.

17.9 Using technology: databases

17.9.1 What is a database?

Spreadsheets are useful for organising and presenting data. However, for very large amounts of information, a database can make it easier to keep the data organised and to search quickly for data that match particular criteria.

You use **databases** all the time without even thinking about them. When you shop for shoes online and you narrow your search by looking only at shoes available in your size or at a particular type of shoe, such as flat sandals, you are actually searching a database and applying filters. Some databases are printed on paper. If you own an address book, it's actually a database that stores information about your friends, including their addresses, landline phone numbers, mobile phone numbers, email addresses and perhaps also their birthdays. You can store the same information in your phone or other electronic device, allowing you to search for a particular friend's details faster.

An address book is a database that contains information about your friends.



The data contained in a database can be organised in a table, although in some instances it would be a table with so many columns that it would not fit easily on a page. For this reason, printed databases are not always set out as a table, but it helps to think of databases as tables of data. If you organised the data in an address book into a table, it would have a number of columns including 'First name', 'Last name', 'Address' and 'Phone number'.

17.9.2 Electronic databases

A database on paper has limitations. You can cross-reference only two things and then usually only in a specific order. For example, in an address book you can look up a person's phone number easily if you look

up their name. You can't do the reverse; that is, you can't look up a phone number and find out the name of the person who has that number (unless, of course, you have enough time to look through the entire address book). Also, the entries are in alphabetical order according to your friend's last name. It is not possible to re-organise the data in order of phone number or street name. If you wanted to find all your friends who live in a particular street, you would need to look through the whole address book.

For this reason, most databases are now stored electronically. Library catalogues used to consist of printed cards stored in drawers but, now, to find a library book you can use a computer to access the library's catalogue. You can **search** for topics, authors, date of publication and more. You can **refine** your search and perhaps look for just magazine articles or videos. You can even read a short summary (synopsis) of each article. This is all possible because computers are very good at storing lots and lots of data and retrieving information very quickly.

Unlike a database on paper, a computer can store data (such as the topic and author of a book) in a table with as many columns as you like and it can search any of the columns rather than just the first one. And it does all this very quickly. The only problem is that a computer can't actually think, so it is up to the person who designs the database to do so very thoughtfully so that it will be easy to search.

Why use an electronic database in science?

Scientists often have huge amounts of data that they need to organise and search (or allow others to search). In 1977, a team led by Australian scientist Fiona Stanley set up the Western Australian Maternal and Child Health Research Database. It stores information about the health of babies and their mothers. Searching and analysing these data has enabled researchers to identify trends and to test whether programs aimed at improving the health of newborn babies are having any effect. This information would have been collected routinely by the doctors and midwives looking after mothers throughout pregnancy and during birth. The database provides a central place to store all the data, and makes it much easier for researchers to find patterns in the data. Important discoveries have already been made using this tool.

Astronomers gather huge amounts of data about the solar system using optical telescopes, radio telescopes and information sent back by space probes. The large amount of information they gather is organised in computer databases so that they, or other astronomers around the world, can search the data to use in their research projects.

As each person on the planet has a unique set of DNA, police can solve crimes by matching DNA samples from crime scenes to DNA information stored on a database.



17.9.3 Designing databases

Just as a table is made up of columns and rows, so too is a database — except that the columns are called **fields** and the rows **records**. If you made the telephone directory into a computer database, it would have three fields: Name, Address and Phone number. Each person's details would then be a record. It would look something like the screenshot below.

Field1	Field2	Field3	Click to Add
Name	Address	Phone number	
T.Eacher	3 School St Belfield	9876 2345	
P.Riest	17 Church Street Holywood	9432 1987	
D.Octor	12 Clinic Crescent Infirmary	9080 7060	

17.9 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.

Analyse and evaluate

Creating a database of Nobel prize winners

Before creating your database, you will need to find some information to put in it. This is best done as a class activity with each student in the class researching one or two Nobel prize winners.

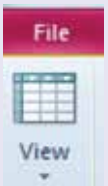
- Use the **Nobel prize** weblink in the Resources tab to find a list of Nobel prize winners.
- Each student in the class should research one or two different Nobel prize winners. Choose people who have won a Nobel prize for work in the categories of Chemistry, Physics or Medicine.
- For each prize winner, collect the data listed below. Ideally the data should be written on cards that can be passed around the class, or they could be typed into a Google doc or wiki so the whole class can add information and access information from other groups.
  - First name
  - Last name
  - Country of birth
  - Year of birth
  - Category of award (such as Chemistry, Physics and Medicine)
  - Organisation (where the person worked)
  - Nobel prize awarded for (one sentence or phrase that outlines the work for which the scientist received the award)
  - Share received (if the award was shared by a group of people)
- Microsoft Access software is commonly used to create databases. The following instructions are for the 2010 edition of this software. If you are using different software, the following instructions will need to be modified.
- Open Access 2010. Click *New* and then *Blank database*. Select the location where the database will be saved, give it a sensible name such as '*Noble prize winners*', and then click *Create*.
- A table will appear. To set up your database, go to design view by clicking on the *Design view* icon in the left-hand corner of the screen. You will be prompted to give the table a name such as 'Table 1'; then click *OK*. A screen should appear. Type in the information that appears in the screen below. Note that the data type should be Text for all fields, even the Year of Birth.



Table1

Field Name	Data Type
ID	AutoNumber
First Name	Text
Last Name	Text
Country of Birth	Text
Year of Birth	Text
Award category	Text
Organisation	Text
Nobel Prize awarded for	Text
Share received	Text

- Now that have designed the database, you can click on the *Datasheet view* button in the top left-hand corner of the screen. You will be prompted to save the table.
- The table [A] should appear. You are now in datasheet view.
- Enter the data that you and your classmates found into the table. In the screen on the following page, the first row is partially completed. When you have entered all the data, save your database.



The great thing about databases is that they allow you to search for data that match particular criteria. This is called running a query. We are going to create a query to find all the Nobel prize winners in our database who were awarded a prize for Medicine and were born in the United States.

- Make sure you are in datasheet view. Click on the *Create* tab. Select *Query wizard* from the ribbon and then *Simple Query wizard*, and click *OK*. The fields in your table will be displayed; click on the ones you want to

appear in the query and then click on the single arrow to move them into the *Selected Fields* box. Select the following fields: First Name, Last Name, Country of Birth and Category. When you have done this, click *Next*. In the next dialog box, enter a name for your query, select *Modify the Query design* and click *Finish*.

- The screen [B] will appear. Now enter the criteria you want the query to look for in the appropriate boxes as shown in the screen. Note that the quotation marks should not be typed in. These will appear automatically.
- Now click on the red exclamation mark (*Run* button) in the toolbar near the top of the screen. The query will run and a table displaying the Nobel prize winners that match your criteria will appear.
- Create a new query to display the Nobel prize winners who won the Nobel prize for Physics and were born in England.

A

Table1

ID	First Name	Last Name	Country of E	Year of Birth	Award categ	Organisatio	Nobel Prize	Share receiv
1	Brian	Schmidt	Australia	1967	Physics	ANU		
(New)								

B

Field:	[First Name]	[Last Name]	[Country of Birth]	[Award category]
Table:	Table1	Table1	Table1	Table1
Sort:				
Show:	☑	☑	☑	☑
Criteria:			"United States"	"Chemistry"
or:				

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Explore more with this weblink: Nobel prize

17.10 Writing your report

17.10.1 Formats

A variety of formats can be used to present a student research project. Your teacher might expect you to give an oral presentation to your class or to prepare a poster or PowerPoint presentation about your project. In most instances, though, your written report should use some of the headings used by scientists when they publish their investigations in scientific journals. You should check with your Science teacher which of the following sections to include in your report.

You may be required to present your research project to your classmates.



Abstract

Briefly describe your experiments and your main conclusions. Even though this appears at the beginning of your report, it is best not to write it until after you have completed the rest of your report.

Introduction

Present all relevant background information. Include a statement of the problem that you are investigating, saying why it is relevant or important. You could also explain why you became interested in the topic.

Aim or problem

State the purpose of your investigation: that is, what you are trying to find out.

Hypothesis

Using the knowledge you already have about your topic, write a statement that will be tested in your investigation.

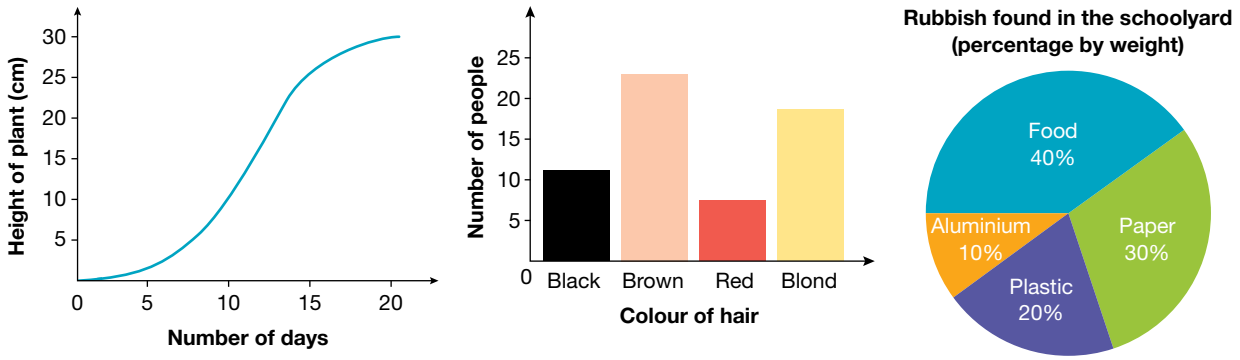
Materials and method

Describe in detail how you did your experiments. Begin with a list of the equipment used and include photographs of your equipment if appropriate. The description of the method must be detailed enough to allow somebody else to repeat your experiments. It should also convince the reader that your investigation is well controlled. Labelled diagrams can be used to make your description clear. Using a step-by-step outline makes your method easier to follow.

Results

Observations and measurements (data) are presented in this section. Wherever possible, present data as a table so that they are easy to read. Graphs can be used to help you and the reader interpret data. Each table and graph should have a title. Ensure that you use the most appropriate type of graph for your data (see pages 700–703).

(Left to right) A line graph, a bar graph and a pie chart. Choose the type of graph that is appropriate to your data.



Discussion

Discuss your results here. Begin with a statement of what your results indicate about the answer to your question. Explain how your results might be useful. Any weaknesses in your design or difficulties in measuring could be outlined here. Explain how you could have improved your experiments. What further experiments are suggested by your results?

Conclusion

This is a brief statement of what you found out and may link with the final paragraph of your 'Discussion'. It is a good idea to read your 'Aim' again before you write your conclusion. Your conclusion should also state whether your hypothesis was supported. Don't be disappointed if it is not supported. Some scientists deliberately set out to reject hypotheses!

17.10.2 Bibliography

Make a list of books and other printed or audiovisual material as well as websites that you have referred to. The list should include enough information to allow the source of information to be easily found by the reader. Arrange the sources in alphabetical order.

The information required for your bibliography depends on the type of resource. For books and journal articles, the following information should be included:

- Author(s) (if known)
- Title of book or article
- Publisher or name of journal/magazine (if not in title)
- Place of publication (if given)
- Date of publication
- Chapter or pages used

- Some examples are listed below.

  Breidahl, H., *Australia's Southern Shores*, Lothian, Melbourne, 1997, Chapter 2.

  World Book Encyclopedia, Volume 4, 1991, pp. 234–236.

  'The Battle of the Bathroom', *Choice*, Sydney, November 1990, pp. 34–37.

It can be more difficult to find an author and date of publication for a website. In addition, you should also provide the name of the website, the URL and the date on which the website was accessed (as web pages may be updated regularly). The easiest way to create a bibliography in the correct format is to use an online bibliography building tool. Use the **Bibliography tools** weblinks in the Resources tab.

Acknowledgements

List the people and organisations who gave you help or advice. You should state how each person or organisation assisted you.

Acknowledge the help you received.



17.10 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. **Identify** which section of your investigation report you should write each of the following in.
   (a) A list of the books and other resources you used to find information for your project
   (b) A table showing all the measurements you recorded
   (c) A diagram of the equipment you used
   (d) The purpose of the experiment
   (e) A brief summary of your investigation and findings
   (f) A statement that relates the results back to the aim and outlines what your results show
2. In a bibliography, why is it important to include the date that a web page was accessed?

Think

3. When scientists write up their investigations for publication in a scientific journal, the abstract is one of the most important parts of the report. **Explain** why the abstract is usually read by many more people than the full report.
4. **Justify** why it is important for scientists to clearly describe the method they used when they write a report of their investigation.
5. **Explain** why it is important for researchers to publish their investigations in scientific journals and to read the reports written by other scientists.
6. Many researchers choose to have their reports published in journals written in English, even if English is not their first language. Suggest why.

Investigate

7. Find out what a patent is and why scientists sometimes patent their ideas.
8. There have been instances where scientists have faked their results or committed other types of scientific misconduct.
   (a) Use the term 'scientific misconduct' in a search engine to find examples of such instances.
   (b) **Outline** why you think that some scientists might be tempted to fake or fabricate their results.
   (c) **Explain** why cases of scientific misconduct are damaging to all scientists.
   (d) What do you think might happen to scientists who are found to have faked their results?

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17.11 Project: Bigger, better beans

learnon

Scenario

The local agricultural show will be running its annual competition to find the biggest bean plant and you are determined that this year you are going to win. In previous years, you have just planted your seeds in their pots, added some fertiliser, put them in the sun and watered them every day but, while the plants did grow, they didn't grow big enough to have a chance at the prize. As a good science student, you know that the growth of plants depends upon the process of photosynthesis, whereby light energy from the sun causes water and nutrients and carbon dioxide to be combined by the plant to produce oxygen and starch (which is a form of chemical potential energy). The plant then uses this starch to grow. So, if the growth of the plants depends upon how much starch is produced, maybe there's something you could do to the plants that would make them produce more starch and grow faster and bigger?

Your task

You will design and carry out an investigation that will test a number of different growth conditions (such as different amounts of sunlight or different substances added to the soil) to determine which will give the greatest rate of growth over a three-week period of time. Your findings will be presented in the form of a scientific report.



17.12 Review

17.12.1 Study checklist

Questions and problems

- **identify** questions and problems that can be investigated scientifically and make predictions based on scientific knowledge and their own observations **17.2**
- use a range of thinking tools to begin planning a student research project **17.3**
- use a range of visual tools to plan a student research project and develop a timeline for the project **17.4**

Investigations and data

- access information from a range of sources including using digital technologies and assess the reliability of gathered information **17.5**
- plan first-hand investigations and identify, in fair tests, variables to be controlled, measured and changed **17.6**
- check the reliability of gathered data **17.4**

Spreadsheets and graphs

- select and construct the appropriate type of grapph (column graph, histogram, sector graph or line graph) to express relationships clearly and succinctly **17.7**
- use spreadsheets to present data and information and to construct graphs **17.8**
- use a database to present data and information **17.9**
- communicate ideas, findings and solutions to probelms using scientific language and representations using digital tehcnologies as appropriate **17.10**
- use a recognised method to acknowledge sources of data and information **17.10**

17.12 Review 1: Looking back

assessON

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. The boiling point of water changes with air pressure. For example, water may not boil at 100 °C at the top of Mount Everest, where the air pressure is less than the pressure at sea level. The following data show the boiling point of water at various air pressures.

Boiling point of water at different air pressures

Air pressure in kilopascals (kPa)	Boiling point of water (°C)
0	0
1	20
7	40
21	60
45	80
101	100
200	120

   (a) Graph the data.
   (b) **Describe** the shape of your graph.
   (c) What is the pressure of the atmosphere at sea level?
   (d) Would it take a longer or shorter time to boil water at the top of Mount Everest, compared with the time it would take at sea level? **Explain** your answer.
2. Draw a cluster map that **summarises** the key ideas in section 17.5.
3. Singalia and Sallyana are two red panda cubs born at Sydney's Taronga Zoo. The table below shows their masses during their first 22 weeks. The photograph at right shows one of the cubs being weighed.



   (a) **Construct** a line graph showing both sets of data on the same set of axes. Use different symbols for the points for each panda and label each line with the panda's name. You may have to extend the vertical axis to fit in the scale for the pandas' masses (or else convert the masses to kilograms and plot in kilograms).

   Interpret the graph from part (a) to answer the following questions.

   (b) **Describe** the growth of each of the panda cubs. How do they compare with each other?
   (c) How long did it take the cubs to double their mass measured in week 1?
   (d) Did the pandas grow at the same rate during the 22 weeks?

Red panda cubs' masses 1996-97 (grams)

Week	Singalia	Sallyana
1	213	219
2	285	290
3	330	349
4	365	377
5	403	408
6	465	452
7	536	514
8	564	576
9	594	610
10	650	637

Week	Singalia	Sallyana
11	703	680
12	714	740
13	814	796
14	872	812
15	956	806
16	1111	786
17	1043	890
18	1130	1000
19	1163	1083
20	1182	1162
21	1225	1218
22	1335	1270

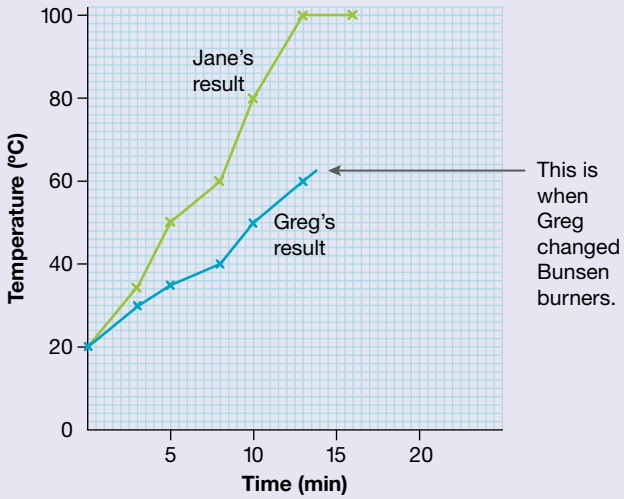
(e) Which were the fastest and slowest growth periods for each panda?
(f) What age was each of the cubs when they reached 1 kg?
(g) **Predict** the age at which each cub will reach 1.5 kg. **Explain** how you made your prediction. What assumption did you make to answer the question?

Test yourself

Use the following scenario to answer questions 1 and 2.
Kimberley and Glenn were walking past their neighbour's house when they noticed that a front window was broken. Glenn told Kimberley that somebody had probably thrown a ball through the window. They had a closer look and noticed clothes scattered all over the floor and drawers open. Kimberley noticed some blood on the broken glass. She told Glenn that the house had been burgled. Glenn agreed and they called the police.

1. The statement 'Kimberley noticed some blood on the broken glass' is
   (A) an observation. (B) a hypothesis.
   (C) a conclusion. (D) an inference. **(1 mark)**
2. Who suggested a hypothesis?
   (A) No-one (B) Glenn only
   (C) Kimberley only (D) Both Glenn and Kimberley **(1 mark)**

Use the following scenario and graph to answer questions 3 and 4.
Jane and Greg decided to test how quickly water would boil when using either the yellow flame or blue flame of the Bunsen burner. They set up identical experiments, except that Jane used a blue flame and Greg used a yellow flame. Their results are graphed below.

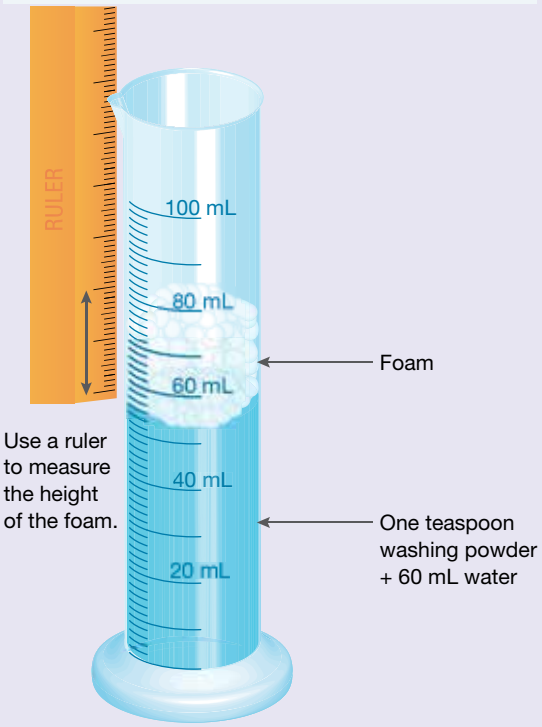


3. What was the temperature of Greg's water when Jane's water reached 100 °C?
   (A) 100 °C (B) 60 °C (C) 62 °C (D) 70 °C **(1 mark)**

4. Jane removed her beaker and Greg quickly placed his beaker over Jane's Bunsen burner. Assuming that the temperature of Greg's beaker did not drop while swapping Bunsen burners, at what time will his water boil?
   (A) 17 minutes (B) 22 minutes
   (C) 15 minutes (D) 18 minutes **(1 mark)**
5. Huang and Tina conducted an experiment to find out if radish plants grow better in the shade. They placed three plants under a veranda at the back of the house and another three in a sunny place in the front yard. All plants were planted in the same soil. Huang and Tina watered each of the plants equally each day.
   (a) Did they conduct a fair test?
   (b) How could Huang and Tina improve the design of their experiment? List as many improvements as possible. **(2 marks)**
6. If you have a front-loading washing machine, you should use 'low-sudsing' washing powder, which produces less foam than other washing powders. Emily did the following experiment to compare how much foam was produced by three brands of washingpowder.
   - She put one teaspoon of each washing powder into separate 100 mL measuring cylinders.
   - She added 60 mL warm water to each measuring cylinder.
   - She shook each measuring cylinder vigorously.
   - She measured the height of the foam produced in each measuring cylinder.The amount of foam produced can be measured with a ruler.



The amount of foam produced can be measured with a ruler.



   (a) **Identify** the independent and dependent variables in Emily's experiment.
   (b) **Identify** the variables that Emily controlled.
   (c) Which variables could have been controlled better?
   (d) Suggest how Emily's experiment could be made more reliable. **(4 marks)**

GLOSSARY

absorbed: the taking in of heat, light, sound or a substance
abundance: the number of a species living within an area
acid: a chemical that reacts with a base to produce a salt and water. Edible acids taste sour.
acid rain: rainwater, snow or fog that contains dissolved chemicals, such as carbon dioxide, that make it acidic. Acid rain can cause rock to weather faster than pure rain can.
acid snow: frozen acid rain
acidity: describes the amount of acid in a mixture. Acids have a sour taste and neutralise bases. Too much acid in water would make it harmful to drink.
adhesion: process of attachment
adhesive forces: force of attraction
aim: purpose
air: the mixture of gases in the atmosphere
air resistance: the force of air pushing on an object as the object moves through the air
airbag: device used in vehicles to lessen impact in collisions
alkali: a base that dissolves in water
allotropes: forms of an element that have different appearances and properties due to differences in their molecular structures. Diamond, graphite and amorphous carbon are allotropes of carbon.
alloy: a mixture of a metal with a non-metal or another metal
alum: the common name for the chemical potassium aluminium sulfate
ammeter: a device used to measure the amount of current in a circuit. Ammeters are placed in series with other components in a circuit.
amniotic fluid: fluid that surrounds the developing baby in the uterus
amorphous solid: solid whose particles are not ordered
ampere: the unit for measuring electric current, usually abbreviated to amps (A)
antacid: a substance containing a base used to treat indigestion. It neutralises excess acid in the stomach.
anthracite: black coal. Anthracite contains less moisture than other forms of coal and releases more energy than the same volume of other coals when burnt.
antibiotics: chemicals that kill bacteria or other micro-organisms
antibodies: chemicals produced by animals to fight some pathogens
aqueous solution: a solution in which water is the solvent
arteries: hollow tubes (vessels) with thick walls carrying blood pumped from the heart to other body parts
assimilate: take in and process something. Living things assimilate substances.
asteroid: one of the millions of rocky bodies that orbit the sun. Some asteroids are like tiny pebbles; others may be hundreds of kilometres in diameter.
asteroid belt: the collection of asteroids that orbit the sun between Mars and Jupiter
asthma: narrowing of the air pipes that join the mouth and nose to the lungs
astronomy: the study of space, including stars, planets, comets and galaxies
atom: a very small particle that makes up all things. Atoms have the same properties as the objects they make up.
atomic number: number of protons in the nucleus of an atom. The atomic number determines which element an atom is.
atomiser: device that produces a fine spray
attract: a pull towards another object
axle: the central part around which a wheel turns
bacteria: the smallest life form found on Earth. Some bacteria are responsible for decay and disease.
balanced: describes forces that are equal but act in opposite directions. Balanced forces cancel each other out.

ball and socket joints: joints where the rounded end of one bone fits into the hollow end of another
ball bearings: steel balls inserted into the hub of a wheel that help the wheel roll around the axle, rather than slide over it. The rolling motion of the ball bearings helps to reduce friction.
bar graph: a diagram using the lengths of rectangles (bars) to show the size of the same property for different objects or at different times. The bars may be horizontal or vertical; also called a column graph.
basalt: a dark, igneous rock with small crystals formed by fast cooling of hot lava. It sometimes has holes that once contained volcanic gases.
base: a chemical that reacts with an acid to produce a salt and water. Edible bases taste bitter.
batholith: intrusive rock mass that measures more than 100 kilometres across
beaker: container for mixing or heating substances
beam balance: an accurate measuring scale used in the science laboratory
bile: a substance produced by the liver that helps digest fats and oils
binary fission: reproduction by the division of an organism (usually a single cell) into two new organisms
bioaccumulation: the accumulation of a substance at higher levels than found in the surrounding environment
biodegradable: able to be broken down into compounds found in nature in a reasonable period of time
biodegradation: the breakdown of chemicals in materials by bacteria or other biological means
biologist: a scientist who studies living things
biology: the study of living things
biomagnification: increase in concentration of a substance that occurs in a food chain
biomass: material produced by living organisms
biomechanics: the study of how animals, including humans, move
biomechanist: a scientist who studies how people move
biostimulant: agent that promotes biological activity
biotic factors: the living things (organisms) in an ecosystem
bituminous coal: coal that forms when lignite is exposed to heat and pressure. It contains less moisture than lignite, but more than anthracite.
blackwater: toilet waste
bladder: sac that stores urine
blood pressure: measures how strongly the blood is pumped through the body's main arteries
blood vessels: the veins, arteries and capillaries through which the blood flows around the body
boiling: the change of state from a liquid to a gas. Boiling occurs when the entire liquid is heated and continues until the liquid turns completely into a gas.
boiling point: the temperature at which a liquid changes to a gas
bolus: round, chewed-up ball of food made in the mouth that makes swallowing easier
bone marrow: a substance inside bones in which blood cells are made
boom: device used to prevent the spread of oil over the surface of water
breathing: movement of muscles in the chest causing air to enter the lungs and the altered air in the lungs to leave. The air entering the lungs contains more oxygen and less carbon dioxide than the air leaving the lungs.
brittle: describes a material that shatters when it is hit
bronchioles: small branching tubes in the lungs leading from the two larger bronchi to the alveoli
Bunsen burner: a device that burns gas, producing a hot flame; used to heat or burn objects in the laboratory
buoyancy: the upward push of water or any other fluid on a submerged or partly submerged object
buoyant: ability to float in a liquid
burning: combining a substance with oxygen in a flame
caesarean section: operation to remove the baby by cutting the mother's abdomen
calcium: a fairly reactive metal that is not found by itself in the body, but as part of many important substances, such as cartilage and bones

calculus: the branch of mathematics concerned with measurement of quantities that are continually changing
calorimeter: a device designed to measure the amount of heat released when a substance burns
canines: sharp, pointed teeth used for tearing and ripping food
capillaries: minute tubes carrying blood to body cells. Every cell of the body is supplied with blood through capillaries.
cardiac muscle: special kind of muscle in the heart that never tires. It is involved in pumping blood through the heart.
carnivore: animal that eats other animals
cartilage: a waxy, whitish, flexible substance that lines or connects bone joints or, in some animals such as sharks, replaces bone as the supporting skeletal tissue. The ears and tips of noses of humans are shaped by cartilage.
cell: the smallest unit of life. Cells are the building blocks of living things. There are many different sized and shaped cells in animals and plants, as well as single-celled organisms.
cell membrane: a structure that encloses the contents of a cell and allows the movement of some materials in and out
cell sap: the mixture of water, dissolved substances, food and waste material found in the vacuoles of plant cells
cell wall: a wall around the cell membrane in plant cells providing a tough extra covering that gives strength and support to the plant cell
cellulose: the cell walls of plants are made of this
centre of gravity: the point of a body where the weight would be concentrated if the body were a single point
centrifuging: separating a mixture by rotating the container quickly. The heavier parts of the mixture move to the outside of the spinning container. Cream is removed from milk by centrifuging.
cervix: the neck of the uterus
charge: (noun) a property of all objects. Charge can be positive or negative. There are some particles inside an atom that have no charge; (verb) to give an object an overall electric charge by adding or removing negative charges. Objects can be charged by rubbing.
chemical engineer: a scientist who combines chemistry and engineering to select materials to develop new products
chemical reaction: a chemical change in which one or more new chemical substances is produced
chemical symbol: the standard way that scientists write the names of the elements, using either a capital letter or a capital followed by a lowercase letter. For example, carbon is C and copper is Cu.
chemical word equation: a representation of a chemical reaction. It lists the reactants involved and the products formed.
chemist: a scientist who studies how substances react with other substances
chemistry: the study of the composition, structure, properties and reactions of matter
chlorine: element added to a water supply to kill harmful micro-organisms
chlorophyll: the green-coloured chemical in plants that absorbs the light energy used in photosynthesis, which makes food from carbon dioxide and water
chloroplast: oval-shaped organelle found only in plant cells. Chloroplasts contain the pigment chlorophyll. They are the 'factories' in which carbon dioxide and water are changed by sunlight and water into food by the process of photosynthesis.
chromatography: a separation technique that separates small traces of substances using differences in solubility
cilia: hair-like tips on cells. The cilia that line your windpipe and lungs help stop germs, dust and fluid getting into your lungs.
circuit diagram: a schematic diagram using representations of wires and components
circulatory system: the body system that circulates oxygen in blood to all the cells of the body. The circulatory system consists of the heart, blood vessels and blood.

classifying: placing organisms or objects into groups based on common characteristics
clastic: describes rocks composed of fragments
clouds: visible collections of small water droplets in the air high above the ground
coal: a sedimentary rock formed from dead plants and animals that were buried before rotting completely
cohesion: intermolecular attraction between molecules
cohesive forces: intermolecular attraction between molecules
colloid: a mixture in which extremely small particles of one substance are spread evenly throughout another substance
column graph: a diagram using the lengths of rectangles (bars) to show the size of the same property for different objects or at different times. The bars may be horizontal or vertical; also called a bar graph.
combustion: the process of combining with oxygen, most commonly burning with a flame
comet: a body composed of rock, dust and ice. When close to the sun, it has a tail that points away from the sun.
compact bone: the hard shell of a bone. The minerals it contains give it strength.
compound: two or more different types of atoms that have been joined (bonded) together
compressible: able to be reduced in volume
concentrated: describes a solution with a considerable amount of dissolved substance per volume of liquid
concentration: measure of dissolved substance per volume of liquid in a solution; removal of unwanted minerals from crushed rock
conclusion: what was found out in an investigation. It is a general statement that sums up a number of observations or the results of an experiment. The conclusion of an experiment relates to the stated aim.
condensation: a change in state from a gas to a liquid; can occur when gas comes into contact with a cold surface
condense: change state from gas to liquid
conducting path: connected series of materials along which an electric current can flow
conducting tissue: a type of tissue in the roots, stems and leaves of plants that transports substances from one part of the plant to another. The two types of conducting tissue are xylem and phloem.
conduction: transfer of heat through collisions between particles
conductor: material that allows electric charge or heat to flow through it
conglomerate: sedimentary rock containing large particles of various sizes cemented together
consumer: organism that relies on other organisms for its food
contact force: a force that acts only between objects that are touching
contaminated: describes a useful substance that contains one or more other substances that affect its use
contract: become smaller in size
control: a parallel experiment where everything is the same as the test set-up except the variable. It is used to ensure that the result is due to the variable and nothing else.
controlled variables: the conditions that must be kept the same throughout the experiment
controlling variables: the process of ensuring that all conditions, except one (the experimental variable), that could affect the results of an experiment are kept the same
convection: transfer of heat through the flow of particles
corona: the sun's bright, hazy atmosphere. It is only obvious when there is a total eclipse. *You must never look at the sun even for a brief moment. You could permanently damage your eyes.*
corrosive: describes a chemical that wears away the surface of substances, especially metals
cotyledons: special leaves of the embryo plant inside a seed that provide food for the developing seedling
cross-pollination: transfer of pollen from stamens of one flower to the stigma of a flower of another plant of the same type
crystalline solid: solid with particles arranged in an orderly pattern forming regular shapes
crystallisation: formation of ordered patterns of particles due to the attraction between particles
cullet: scraps of broken glass
cusp: ridge or point on the surface of molars and premolars

cytosol: liquid found inside cells
data: observations or measurements made and recorded during an investigation
database: an organised collection of information
decanting: pouring liquid off the top when sediment has settled to the bottom of the container
decomposers: small organisms that break down dead and decaying matter
decomposition: breaking up of a substance into smaller parts
deforestation: the removal of trees from the land
density: measure of mass per volume of a substance; the number of a species living within an area
deoxygenated: describes blood from which some oxygen has been removed
dependent variable: a variable that is expected to change when the independent variable is changed. The dependent variable is observed or measured during the experiment.
deposition: reverse of sublimation; laying down of weathered rock particles and soil by rivers, wind, oceans and glaciers
diagnose: to identify a disease or condition
diamond: colourless, sparkling crystal valued in jewellery for its beauty. It is a three-dimensional arrangement of carbon atoms that differs from the layers in graphite.
diaphragm: flexible, dome-shaped, muscular layer separating the chest and the abdomen. It is involved in breathing.
diastolic pressure: the lower blood pressure reading during relaxation of the heart muscles
dichotomous key: a diagram used to classify things, by grouping them into smaller and smaller groups that are more and more alike, based on choosing one of two features
differentiate: examination of the differences
diffuse: spread throughout another substance
diffusion: the spreading of one substance through another due to the movement of their particles
dilute: describes a solution with a small amount of dissolved substance per volume of liquid
disperse: scatter
displacement: formation of a solid chemical by another during a chemical reaction
dissolved: describes a substance that has mixed completely with a liquid so that it is no longer visible. Dissolving requires the substance to separate into very small particles.
distillate: the liquid collected during distillation when the evaporated substance condenses
distillation: a separation technique that uses evaporation to separate substances. The mixture is heated so that one substance evaporates. The vapour is collected and condenses into a liquid.
distilled water: pure water collected by condensing steam
distribution: the area inhabited by a plant or animal species
divided bar graph: a type of bar graph where bars are divided into sections to represent parts of a whole
domain: a 'mini-magnet' found in magnetic materials
drag: the force that acts on an object moving against air or water
dry cells: devices containing chemicals as solids and pastes that react to supply an electric charge
ductile: able to be drawn into a wire
earth science: the study of the Earth
ecology: the study of the way in which organisms interact with other organisms and their environment
ecosystem: community of living things that interact with each other and with the environment in which they live
ejaculated: a release of sperm
ejaculation: the discharge from the penis of a small quantity of semen
electric circuit: the path that electrons flow along. Electrons require a closed path of conductors for electricity to flow.
electric current: a measure of the number of electrons flowing through a circuit every second. An increase in current means an increase in the rate of flow of electrons in the circuit.

electrical energy: energy produced by electrons
electrocardiogram (ECG): graph made using the tiny electrical impulses generated in the heart muscle, giving information about the health of the heart
electrochemical reaction: reaction involving the transfer of electrons
electrodes: conductors through which an electric current enters or leaves an electric cell
electrolysis: use of an electric current to supply energy for a chemical reaction. One reactant gains electrons (reduction) and another reactant loses electrons (oxidation).
electrolyte: acid, base or salt that conducts electricity when dissolved in water or melted
electromagnet: a magnet formed by wrapping a coil of wire around an iron core. When electricity passes through the coil, the iron core becomes magnetic.
electronic scales: device for measuring mass, in grams (g) and kilograms (kg)
electrons: negatively charged, very light particles of an atom. Electrons move around the central nucleus of the atom.
electrostatic charge: electric charge present on an insulated body
electrostatic force: a non-contact force of electric charges at rest. We experience electrostatic forces when we pull off a jumper and our hair stands on end.
element: pure substance made up of only one type of atom
embryo: group of cells formed from the zygote and developing into different body organs
emulsify: combine two liquids that don't normally mix easily
emulsion: a colloid with droplets of one liquid spread evenly through another
endosperm: food supply for the embryo plant in a seed
endothermic: a chemical reaction that takes in heat from the surroundings
energy: the ability to make something happen, such as moving something or making a light glow
engineer: a person who uses designs or scientific ideas to design and build devices or structures or new technology for a useful purpose and make it work
environment: the living and non-living things that affect organisms in a particular place that is, the surroundings of a living thing
environmental impact statement (EIS): study of the possible effects of a planned project on the environment
enzymes: special chemicals that speed up reactions but are themselves not used up in the reaction
epiglottis: leaf-like flap of cartilage behind the tongue that closes the air passage during swallowing
erosion: the process of moving weathered rock or soil from one place to another
evaporate: change state from liquid to gas
evaporation: a change in state from liquid to gas. Evaporation occurs only from the surface of the liquid.
excrete: remove wastes from the body
exoskeleton: skeleton or shell that lies outside the body
exothermic: a chemical reaction that releases heat to the surroundings
expand: increase in size due to the movement of particles in a substance
extrapolation: use of a graph to determine unmeasured data values beyond the range of measured data values
extrusive rock: igneous rock that forms when lava cools above the Earth's surface
fair test: a method for determining an answer to a problem without favouring any particular outcome another name for a controlled experiment
fallopian tubes: tiny tubes joining the ovaries to the uterus. Fertilisation occurs in one of these tubes.
fault: a break in a rock structure. The rock on either side of the break can move.
fertilisation: penetration of the ovum by a sperm; penetration of ovules in a flower by male sex cells in pollen
fertilised: an egg cell is fertilised when a male sex half-cell enters it. In animals, the male sex cell is the sperm; in plants, it is contained in the pollen. A fertilised egg eventually grows into a new organism.
fetus: individual in the uterus after eight weeks of development
field: in a database, type of information recorded in a column for each record

filaments: thin threads
filter: a device that allows some materials to pass through. It blocks particles too large to fit through the holes or pores.
filter funnel: used with filter paper to separate solids from liquids
flammable: describes substances such as methylated spirits that burn easily
floatables: substances that are less dense than water so can float on water
floc: a clump of particles heavy enough to sink to the bottom rather than remain floating in a liquid
flocculation: the process of adding a chemical to a suspension to create flocs, which settle to the bottom
fluid: a substance that flows and has no fixed shape. Gases and liquids are fluids.
fluoride: substance added to a water supply to help prevent tooth decay
fog: a visible collection of small water droplets in the air at ground level
folding: the buckling of rocks. It is caused when rocks are under pressure from both sides.
follicles: sacs containing egg cells
force: (noun) a push, pull or twist. Forces are measured in newtons (N). (verb) to push, pull or twist
fossil: evidence of life in the past
fossil fuel: substance, such as coal, oil and natural gas, that has formed from the remains of ancient organisms. Coal, oil and natural gas are often used as fuels; that is, they are burnt in order to produce heat.
fracture: in relation to identifying minerals from their properties, a mineral's fracture describes the appearance of the break when a sample of the mineral is snapped
freezing: change of state from liquid to solid
friction: a force that acts against the movement of an object. It occurs between any surfaces that are touching and trying to move past each other.
fruit: ripened ovary of a flower, enclosing seeds
fuel: a substance that is burnt in order to release energy, usually in the form of heat
galvanising: protecting a metal by covering it with a more reactive metal that will corrode first
gangue: leftover waste rock and mineral material. It is produced during the processes that extract mineral ores.
gas: state of matter with no fixed shape or volume
gas giant: a large planet mostly made up of gas. Jupiter is a gas giant.
geologist: a scientist who studies the structure of the Earth, especially its rocks
geothermal energy: energy produced by the temperature difference between different places on or in the Earth
germination: first sign of growth from the seed of a plant
global warming: an increase in the Earth's temperature over a period of many years
granite: a hard, igneous rock with different coloured crystals large enough to see. It forms slowly below the Earth's surface.
graphite: a black form of carbon easily rubbed onto other substances
gravitational attraction: an attraction that exists between any two bodies in the universe that have mass
gravitational energy: type of energy from the Earth's gravitational force that causes objects above the ground to fall to Earth. The higher an object, the more gravitational energy it has.
gravity: the force of attraction that exists between any two bodies in the universe that have mass. The gravity at the Earth's surface is the pull on objects near its surface towards the centre of the Earth.
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.
greenstick fracture: a break that is not completely through the bone, often seen in children
greywater: water from the laundry and bathroom
ground water: rainwater that has soaked into the lower levels of the soil and has saturated the soil
groyne: a jetty built into the sea to prevent the erosion of the beach
guard cells: cells on either side of a stoma that work together to control the opening and closing of the stoma

habitat: the place where an organism lives
haemoglobin: the red pigment in red blood cells that carries oxygen
hardness: a property of a mineral that can be found using Mohs' hardness scale. For example, if a mineral sample can be scratched by a piece of quartz but not by orthoclase, its hardness lies between 6 and 7.
heartbeat: contraction of the heart muscle occurring about 60–100 times per minute
heat: energy that moves from one place to another place that is at a lower temperature
heatproof mat: surface that protects benches from damage by heat and chemicals
helitorch: device used in aerial firefighting
herbivores: animals that eat only plants
heresy: stating an opinion that goes against the orthodox teachings of a religion
hinge joints: joints in which two bones are connected so that movement occurs in one plane only
histogram: a graph with equal intervals marked on the *x*-axis for the values of a quantity, and frequency of occurrence of each value shown by the height of adjoining columns
histologist: a scientist who studies the cells and tissues that make up animals, including humans. Histologists look at small samples of cells and tissues under microscopes.
Hofmann voltameter: device used to measure voltage in an electric circuit
homogenisation: process of creating uniformity in a solution
humus: organic matter resulting from the decomposition of plant and animal tissue in the soil. Humus helps the soil hold water and mineral nutrients needed by plants.
hydrocarbons: compounds containing only hydrogen and carbon atoms
hydroelectric energy: energy produced by the movement of water
hydrogen: the element with the smallest atom. By itself, it is a colourless gas and combines with other elements to form a large number of substances, including water. It is the most common element in living things.
hydrologist: scientist who studies water on Earth
hypothesis: a suggested explanation for past observations that is tested in an experiment
immovable joint: joint that allows little or no movement, except when absorbing a hard blow
incandescence: ability to produce light
incisors: teeth with straight, sharp edges that are used for biting and cutting food
incompressible: unable to be reduced in volume
incubated: placed in a cabinet that maintains an optimum temperature for bacterial growth
independent variable: the variable that the scientist changes to observe its effect on another variable
indicator: a substance that changes colour when it reacts with acids or bases. The colour shows how acidic or basic a substance is.
indigestion: a chemical reaction in the stomach related to difficulties in digesting food. Indigestion can cause discomfort, burping and stomach rumbling.
industrial chemist: scientist who uses chemistry to create new materials, such as synthetic fibres
inference: a logical explanation about what happened and why it happened
infra-red radiation: invisible radiation emitted by all objects. You feel infra-red radiation as heat.
insect-pollinated flowers: flowers that receive pollen carried on the body parts of insects from other flowers
insoluble: unable to be dissolved
insulator: material that does not allow heat to move through it
interpolation: use of a graph to determine unmeasured data values within the range of measured data values
intrusive rock: igneous rock that forms when magma cools below the Earth's surface
investigation: activity aimed at finding information
involuntary muscles: muscles not under the control of the will; they contract slowly and rhythmically. These muscles are at work in the heart, intestines and lungs.
irrigate: apply water to
Jupiter: the largest of the planets, with 17 satellites

keratin: hard natural polymer
kilogram (kg): the unit in which mass is measured
kinetic energy: energy due to the motion of an object
landfill: an area set aside for the dumping of rubbish
larvae: a stage in the life cycle of egg-laying animals. It is the stage after the egg hatches.
lattices: the giant networks formed when atoms share their electrons
lava: a mixture of molten rock and gases that has reached the Earth's surface from a volcano
leaching: removing soluble substances when they dissolve in water that penetrates the ground
left atrium: upper left section of the heart where oxygenated blood from the lungs enters the heart
left ventricle: lower left section of the heart, which pumps oxygenated blood to all parts of the body
ligament: band of tough tissue that connects the ends of bones or keeps an organ in place
light: radiation to which our eyes are sensitive, making it possible to see objects that emit or reflect it
lightning: the spark caused when built-up charges in a cloud discharge quickly to other clouds or the ground
lightning rod: conductive metal rod, often attached to the tops of tall buildings. Lightning rods help to keep buildings safe from lightning strikes.
lignin: a hard substance in the walls of dead xylem cells that make up the tubes carrying water up plant stems. Lignin forms up to 30 per cent of the wood of trees.
lignite: brown coal. This moist coal forms from peat that is exposed to heat and pressure. There are large deposits of lignite in south-east Victoria.
lignotuber: a lump on the roots of a tree that sprouts after a fire
lime: compound (calcium hydroxide) added to a water supply to reduce acidity
limestone: a sedimentary rock formed from the remains of sea organisms. It consists mainly of calcium carbonate.
line graph: a graph made by plotting pairs of data as points and joining the points together, or drawing a line through the middle of the points, called the 'line of best fit'
liquid: state of matter that has a fixed volume, but no fixed shape
load: device that uses electrical energy and converts it into other forms of energy
lub dub: the sound made by the heart valves as they close
lubricant: substance with large particles that can slide easily over each other. Lubricants are used between surfaces that rub against each other to reduce wear and increase motion between the surfaces.
lustre: describes how a mineral reflects light from its cut surface. Lustre may be described as dull, metallic, pearlescent, glassy, brilliant, waxy or silky.
magma: a very hot mixture of molten rock and gases, just below the Earth's surface, that has come from the mantle layer below the Earth's outer crust
magnet: substance able to attract iron or other magnetic materials
magnetic field: a map of lines showing the size and direction of a magnetic force. The size of the force is shown by how close together the lines are. The direction at any point is given by the direction in which the north pole of a magnet would face.
magnetic force: the force (push or pull) that acts between magnets (including the Earth) and magnetic objects
magnetic North Pole: the place on Earth to which the north pole of a magnet is attracted
magnetic South Pole: the place on Earth to which the south pole of a magnet is attracted
malleability: ability to be bent or folded
manufacturing processes: processes used to make products
Mars: a small planet near Earth. Space probes have brought back samples from Mars.
mass: the quantity of matter in an object (usually measured in grams or kilograms)
massive: describes an object with a very large mass
matter: anything that has mass and takes up space. The three main states of matter are solid, liquid and gas.
mayu: the Incan name for the bright stars in the Milky Way, meaning river

measuring cylinder: used to measure volumes of liquids accurately
melting: the change of state from solid to liquid
melting point: the temperature at which a solid substance turns into a liquid (melts) or a liquid turns into a solid (freezes)
meniscus: the curved upper surface of a column of liquid
Mercury: the small planet nearest the sun
metal: element that conducts heat and electricity; shiny solid that can be made into thin wires and sheets that bend easily. Mercury is the only liquid metal.
metal extraction: separation of metal from the surrounding rocky material
metalloids: elements that have the appearance of metals but not all the other properties of metals
metamorphic rock: rock formed from another rock that has been under great heat or pressure (or both)
metamorphism: the process that changes rocks by extreme pressure or heat (or both)
meteor: the fiery streak of light from a meteoroid that has entered the Earth's atmosphere from space and has become so hot that it burns
meteorite: a fallen meteoroid that has reached the Earth's surface
meteoroid: small bodies of rock and/or metal travelling through space
mineral extraction: separation of minerals from the surrounding ore
mineral ores: valuable resources found in rocks
mineral salts: chemical compounds that occur naturally and belong to the group called salts. Many dissolve in water and contain elements that are essential for healthy plant or animal growth.
minerals: substances that make up rocks. Each mineral has its own chemical make-up.
mining: extraction of resources from the Earth
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
mixture: a combination of substances in which each keeps its own properties
Mohs' hardness scale: scale developed by the geologist Friedrich Mohs. It consists of a comparative list of ten minerals arranged in order from softest (hardness value of 1) to hardest (10). A harder mineral scratches a softer mineral.
molars: teeth with a large rough surface used for grinding food
molecule: two or more atoms joined (bonded) together, forming a small particle
monochloramine: a type of disinfectant added to the water supply to kill dangerous bacteria or micro-organisms
monomer: a small repeating unit that makes up a polymer. A monomer is a molecule, usually containing carbon and hydrogen, and sometimes other elements.
moulds: cavity in a rock that shows the shape of the hard parts of an organism; types of fungi found growing on the surface of foods
mudstone: a fine-grained, sedimentary rock without layering
multicellular: having many cells. Most plants and animals are multicellular.
native elements: minerals in their pure form, such as gold and diamonds
natural fibres: fibres that form naturally; that is, they have not been made by humans. Natural fibres include wool and silk from animals and cotton from plants.
natural resources: naturally occurring raw materials that mankind uses for production, consumption or trade
neap tide: a weaker high and low tide that occurs when the sun and moon are not in the same line as the Earth. At such times, the gravitational pull of the sun and the moon work against each other.
nectary: gland secreting a sugary fluid
negative electric charge: the charge on an atom or object with more electrons than protons

negatively charged: having more electrons than protons (more negative charges than positive charges)
Neptune: a small planet near the edge of the solar system, with an atmosphere of methane gas
neuropsychologist: a scientist who studies different areas of the brain to better understand brain functions such as memory and learning
neutralisation: a reaction between an acid and a base. A salt and water (a neutral liquid) are the products of this type of reaction.
neutron: tiny, but heavy, particle found in the nucleus of an atom. Neutrons have no electrical charge.
newton (N): the unit for measuring forces
Nobel Prize: one of six international prizes awarded annually for outstanding achievement in physics, chemistry, medicine, literature, economics and the promotion of peace
non-contact force: a force that acts between objects even though the objects are not touching
non-metal: element that does not conduct electricity or heat. Non-metals melt and turn into gases easily and are brittle and often coloured.
nuclear energy: energy produced by harnessing the radiation produced by the nuclei of atoms
nucleic acid: molecules composed of building blocks called nucleotides linked together in a chain
nucleon: one of the particles present in a nucleus, such as a proton or neutron
nucleus: the roundish structure inside cells that acts as the control centre for the cell. Central part of an atom, made up of protons and neutrons. Plural nuclei
nutrients: substances that provide energy and chemicals that living things need to stay alive, grow and reproduce
nylon: synthetic fibre. The monomers are joined by the elimination of water molecules at the joins.
observation: information obtained by the use of our senses or measuring instruments
obsidian: a black, glassy rock that breaks into pieces with smooth shell-like surfaces
ocean wave energy: energy produced by the movement of ocean waves
off-shore: away from the shore
oil spill dispersants: chemicals that can break up oil spills into droplets, which are more easily dispersed
omnivores: animals that eat plants and other animals
open-cut mining: mining technique used to extract resources found close to the Earth's surface. Soil and vegetation are removed and excavators dig directly into the surface.
orbit: the path that an object follows when it moves all the way around another object, such as the path of the Earth around the sun
ore bodies: rocks containing large amounts of a particular mineral
organ: group of tissues working together to carry out a particular job
organelle: small structure in a cell with a special function
organic sedimentary rocks: sedimentary rock that contains significant amounts of organic carbon
organism: living thing
ossification: hardening of bones
osteoporosis: loss of bone mass that causes them to become lighter, more fragile and easily broken
ovary: the hollow, lower end of the carpel containing the ovules (the female egg cells)
overburden: material that lies above underground resources
ovule: receptacle within an ovary that contains egg cells
ovum: female gamete or sex cell
oxidation: chemical reaction involving the loss of electrons by a substance
oxygen: a gas in the air (and water) that animals need to breathe in; made up of particles with two oxygen atoms. Plants produce oxygen as part of photosynthesis.
oxygenated: describes the bright red blood that has been supplied with oxygen in the lungs
oxyhaemoglobin: haemoglobin with oxygen molecules attached
pacemaker: electronic device inserted in the chest to keep the heart beating regularly at the correct rate. It works by stimulating the heart with tiny electrical impulses.

palaeontologist: a scientist who studies fossils
paper chromatography: method of separating a mixture of different colours. The liquid soaks through the paper and carries the mixture with it. Some substances in the mixture are carried through the paper faster than others so the substances are separated along the paper.
paper mill: place where paper products are manufactured
parallax error: the error that occurs when scales are read inaccurately from an angle
parallel circuit: 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.
partial lunar eclipse: phenomenon that occurs when the shadow of the Earth partially obscures the moon
partial solar eclipse: phenomenon that occurs when the shadow of the moon partially obscures the sun
particle model: a description of the moving particles that make up all matter and how they behave. The model explains the properties of solids, liquids and gases.
peat: compressed vegetable matter that can be dried and used as fuel
penicillin: substance, first extracted from moulds, that kills many types of bacteria. It was the first antibiotic drug.
penis: external male sex organ through which urine and semen pass
penumbra: the lighter, outer part of a shadow
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.
peristalsis: the process of pushing food along the oesophagus or small intestine by the action of muscles
petals: the coloured parts of a flower that attract insects
Petri dish: a shallow, circular glass dish, often used in the laboratory for growing bacteria
petroleum: crude oil, made of a mixture of hydrocarbon compounds
pH scale: scale from 1 (acidic) to 14 (basic) that measures how acidic or basic a substance is
pharmaceutical industry: an industry that manufactures medicines and other medical treatments
pharmacology: the study of the effects of drugs on living things
phenolics: molecules that may act as signalling or defence molecules
phloem: type of tissue that transports sugars made in the leaves to other parts of a plant
phosphorus: a substance that plays an important role in almost every chemical reaction in the body. Together with calcium, it is required by the body to maintain healthy bones and teeth.
photosynthesis: the food-making process in plants that takes place in chloroplasts within cells. The process uses carbon dioxide, water and energy from the sun.
photosynthesise: what a plant does when it uses carbon dioxide, water and the sun's energy to make food
physicist: a scientist who studies the laws of nature
physics: the study of matter and energy
physiology: a study of how the parts of living things work together
physiotherapist: a person who treats body weaknesses through massage and exercise
pie chart: a diagram using sectors of a circle to compare the sizes of parts making up the whole
pivot joint: joint that allows a twisting movement
plankton: microscopic animals and plants that float in sea water
plasma: gas-like state of matter
plasma: the yellowish, liquid part of blood that contains water, minerals, food and wastes from cells
plastic: synthetic substance capable of being moulded
platelets: small bodies involved in blood clotting. They are responsible for healing by clumping together around a wound.
plumule: small bud at the tip of the embryo plant in a seed
plutonic rocks: igneous rocks that form when magma cools below the Earth's surface; also called intrusive rocks
poles: two areas of a magnet (the north and south poles) where the magnetic force is the strongest

pollination: transfer of pollen from the stamen (the male part) of a flower to the stigma (the female part) of a flower
polyester: synthetic fibre. The monomers are joined together by the elimination of water molecules at the joins.
polyethylene: polymer composed of ethene monomers
polymer: substance made by joining smaller identical units. All plastics are polymers.
polyvinyl chloride (PVC): polymer composed of chloroethene monomers
porous: describes a surface that is full of small pores or holes through which fluids can pass
positive electric charge: the charge on an atom or object with fewer electrons than protons
positively charged: having more protons than electrons (more positive charges than negative charges)
potable water: drinking water
potential energy: energy that has the potential to do work and so the energy is 'stored', such as gravitational energy, elastic energy and chemical energy
powdery substance: substance that is in a fine solid form
power supply: a device that can provide an electric current
precipitate: solid product of a chemical reaction that does not dissolve in water
predators: animals that hunt other animals for food
premolars: teeth with two points that roll and crush the food
pressure: a push or squeeze on an object
prey: animal hunted by other animals for food
producers: organisms, such as plants, that use photosynthesis to make their own food from the sun's energy
product: new chemical substance that results from a chemical reaction
properties: characteristics or features of an object or substance
proton: tiny, but heavy, particle found in the nucleus of an atom. Protons have a positive electrical charge.
psychology: the study of the brain and its functions
pulse: alternating contraction and expansion of arteries due to the pumping of blood by the heart
pumice: a pale rock that forms when frothy lava cools in the air. Pumice often floats on water as it is very light and full of holes that once contained gas.
pure substances: matter composed entirely of one type of atom or molecule
purification: removal of impurities
qualitative: type of observation that describes what is seen
quantitative: type of observation where a measurement with a specific value is used
quinones: molecules formed from reactions between phenolics and oxygen
radiant heat: heat that is transferred from one place to another by radiation
radiation: a method of heat transfer that does not require particles to transfer heat from one place to another; the energy produced by the nucleus of an atom
radicle: root of the embryo plant in a seed
rainwater: water captured from the roof in rainwater tanks
react: be involved in a chemical change
reactant: chemical substance used up in a chemical reaction. Some chemical bonds in a reactant are broken during the reaction.
reaction rate: measure of how quickly a process occurs
record: a collection of information about one object in a row of a database
recycled water: water derived from sewerage systems or from industrial processes
recycling program: a program often run by local councils to collect recyclable materials from people's homes
red blood cells: living cells in the blood that transport oxygen to all other living cells in the body. Oxygen is carried by the red pigment haemoglobin.

refine: restrict a search
reflected: when heat, light or sound is not absorbed but is completely thrown back
rehabilitated: restored to its previous condition
relative dating: comparing the ages of rocks without actually knowing their ages in years
reliable: describes consistent results obtained from repeated experiments
renewable resources: resources that are replaced easily. Energy from the sun, wind and water are renewable resources.
repel: push away
repulsion: a push away from another object
respiration: the chemical process that takes place in every cell to release energy. Glucose reacts with oxygen to produce carbon dioxide and water.
reverse osmosis: water purification process that uses a semipermeable membrane
right atrium: upper right section of the heart where deoxygenated blood from the body enters
right ventricle: lower right section of the heart, which pumps deoxygenated blood to the lungs
root hairs: tube-like outgrowths of cells on the surface of roots. They have thin walls, which allow water and dissolved substances to move into the root.
rotate: turn around on an axis
rust: red-brown substance that forms when iron reacts with water and oxygen in the air
safety glasses: plastic glasses used to protect the eyes during experiments
saliva: watery substance in the mouth that moistens food before swallowing
sandstone: a sedimentary rock with medium-sized grains. The sand grains are cemented together by silica, lime or other salts.
saturation: the point at which no more solute will dissolve in a solvent at a particular temperature
Saturn: a large planet famous for the rings of material around its equator
scavengers: animals that eat dead plant and animal material
scientists: people skilled in or working in the fields of science; scientists use experiments to find out about the material world around them
scoria: a dark, igneous rock formed from gassy lava that cools quickly
scrotum: pouch of skin containing testes. It hangs outside the body to keep the sperm cooler than normal body temperature.
search: the use of a computer to find information in a database
sector graph: diagram using sectors of a circle to compare the sizes of parts making up the whole
sediment: the material that collects when suspensions are left to stand. Insoluble substances that collect at the bottom of a container are sediments.
sedimentary rocks: rocks formed from sediments deposited by water, wind or ice. The sediments are cemented together in layers, under pressure.
seed: product of a fertilised ovule
seed coat: the protective layer around a seed
seedling: young plant produced from the embryo in a seed after germination
self-pollination: transfer of pollen from the flower's own stamen to its stigma
semen: combination of fluid and sperm
sensor: device connected to an instrument such as a data logger that measures and sends information
sepal: flower part
separate: to divide into parts
separating funnel: a pear-shaped glass container, with a tap at its base, used to separate two liquids that do not mix. Opening the tap removes the bottom liquid and the liquid floating on top is left in the funnel.
separation: the process of dividing a mixture into its parts
septic tank: a sewage treatment system placed underground in backyards of houses not connected to town sewage treatment plants

series circuit: a circuit with the components joined one after the other in a single continuous loop
sewage: a mixture of water and substances that flow from laundries, bathrooms, kitchens and toilets
sewerage: the system of drains and pipes that takes sewage away from a property
shale: a fine-grained rock formed in layers by the consolidation of clay
sieving: separating particles of different sizes by allowing the smaller particles to fall through holes in a container
silk: a natural polymer
siltstone: a sedimentary rock with a particle size between that of sandstone and mudstone
skimmer: device that removes the floating particles from a solution
smelting: production of a metal in its molten state
solar energy: energy sent out into space from the sun
solid: state of matter that has a fixed shape and volume
solubility: a property of a substance that describes how quickly it dissolves. Substances with different solubilities dissolve at different rates.
soluble: able to be dissolved
solute: a substance that is dissolved in a solvent to form a solution
solution: a mixture of a solute dissolved in a solvent. Solutions are transparent (clear) but may be coloured.
solvent: a substance in which a solute dissolves to form a solution
sperm: male reproductive cell. It consists of a head, a middle section and a tail used to swim towards the egg.
sperm cell: the male reproductive cells produced in the testes
spinneret: device like a nozzle with small holes through which a plastic material passes, forming threads
spongy bone: bone tissue with a lattice-like structure that is less dense than compact bone
sports psychologist: someone who studies how athletes train their minds to help produce greater success in the sports arena
sports psychology: the study of how athletes train their minds to help produce greater success in the sports arena
spring balance: device that can measure mass using a spring
spring tide: very high tide that occurs when there is a new or full moon. At such times, the Earth experiences the combined gravitational attraction of the sun and the moon because all three bodies are in a straight line.
stamen: male part of the flower; includes the anther (containing the pollen) and the stalk to which it is attached (the filament)
starch: a complex carbohydrate that stores energy in plants
states of matter: these include solid, liquid, plasma and gas
static electricity: a build-up of charge in one place
stigma: the female part of a flower, at the top of the carpel, that catches the pollen during pollination
stomata: small openings located mainly on the lower surface of leaves. These pores are opened and closed by guard cells. Singular stoma.
stormwater: water that runs off surfaces into stormwater drains after heavy rain
streak: the colour and texture of the mark that a mineral leaves behind when it is scratched across a hard white surface
streamlined: shaped so that drag through a fluid is minimised
style: flower part
sublimation: the change in state from a solid into a gas without first becoming a liquid (or from a gas into a solid without first becoming a liquid)
substance: something made of matter
surface protection: coating over a metal surface to prevent corrosion

surface tension: the 'firmness' of the surface of a liquid created by the attraction between particles at the surface. The surface acts like an elastic skin.
surfactant: chemical that can disperse oil and water and lower surface tension
suspended: hanging, not falling or sinking
suspension: a mixture of a gas or liquid and an insoluble substance. The insoluble substance settles to the bottom when the mixture is left to stand.
sustainable: able to maintain long-term biological productivity over time
synovial fluid: the liquid inside the cavity surrounding a joint. Helps bones to slide freely over each other.
synthesis: formation
synthetic: manufactured by humans
system: several organs working together. For example, the brain and spinal chord make up the central nervous system.
systolic pressure: the higher blood pressure reading during contraction of the heart muscles
tailings: solid waste products from metal extraction
temperature: a measure of how hot or cold a substance is. It is measured in degrees Celsius.
terrestrial planet: Earth-like planet that is small and solid
test tube: thin glass container for holding, heating or mixing small amounts of substances
testes: organs that produce sperm and sex hormones
thermometer: instrument used to measure temperature. Most school thermometers contain alcohol that is dyed red. As the temperature rises, the alcohol expands up a thin column in the thermometer. The length of the alcohol column indicates the temperature. Extra care must be taken with thermometers containing mercury as it is poisonous.
thinking hats: method of analysing ideas and concepts
tidal energy: energy produced by the movement of ocean waves or water
tidal range: the difference between the higher of the high tides and the lower of the low tides on a given day
tissue: a group of cells that come together to perform a specific function. For example, muscle tissue is formed by muscle cells, and nerve tissue is formed by nerve cells.
tooth decay: the formation of holes in the surface of teeth
total lunar eclipse: phenomenon that occurs when the shadow of the Earth completely obscures the moon
total solar eclipse: phenomenon that occurs when the shadow of the moon completely obscures the sun
toxic: describes chemicals that are dangerous to touch, inhale or swallow
trace fossils: fossils that provide evidence, such as footprints, that an organism was present when the rock was formed
trachea: narrow tube from the mouth to the lungs through which air moves
traction: a force that keeps objects from slipping or losing contact with a surface. Traction is similar to friction.
transferred: moved from one place to another
transformed: energy changed from one form to another
transfusion: injection of blood from another person into your veins to replace the blood you have lost
translocation: transport of materials, such as water and glucose, in plants
transmitted: sent out or broadcast
transmutation: process of changing one element into another
transparency: ability of a substance to allow light to pass through it
trial: repetition of an experiment. Increasing the number of trials increases the reliability of the experiment.
turbine: device that rotates when exposed to wind or water movement
ultraviolet (UV) rays (radiation): invisible radiation very similar to violet light, but not visible, more energetic and able to damage skin cells
umbra: the darker, central part of a shadow

unbalanced: describes two or more forces that do not cancel each other out. Unbalanced forces can start an object moving, speed it up, slow it down, change its direction or change its shape.
underground mining: mining below the surface of the Earth, rather than surface or strip mining
unicellular: describes an organism having only one cell
universe: all of space and the matter and energy contained in it
unspecialised: not specialised
Uranus: a small planet with an unusual rotation. It spins rapidly, with its axis of rotation pointed towards the sun.
ureter: tube from each kidney that carries urine to the bladder
urethra: tube through which urine is emptied from the bladder to the outside of the body
urination: passing of urine from the bladder to the outside of the body
urine: yellowish liquid, produced in the kidneys. It is mostly water and contains waste products from the blood such as urea, ammonia and uric acid.
vacuole: a sac within a cell used to store food and wastes. Plant cells usually have one large vacuole. Animal cells may have several small vacuoles or none at all.
vagina: the elastic passage in the female body that connects the uterus to the vulva
valves: flap-like folds in the lining of a blood vessel or other hollow organ that allow a liquid, such as blood, to flow in one direction only
variable: quantity or condition in an experiment that can change
vena cava: large vein leading into the top right chamber of the heart
verdigris: the whitish green coating that develops on bronze when it has been exposed to air and moisture
viscosity: property of the thickness of a liquid. A viscose liquid, such as tar, is very thick.
vital capacity: the largest volume of air that can be breathed in or out at one time
volt: measure of electrical energy
voltage: the amount of energy contained in electrons flowing in an electric circuit
voltmeter: a device used to measure the amount of energy used by a component in a circuit. Voltmeters are placed in parallel with the components that they are measuring.
volume: the amount of space taken up by an object or substance
voluntary muscle: muscle attached to bones; it moves the bones by contracting and is controlled by an animal's thoughts
water: a colourless liquid made up of particles containing two hydrogen atoms bonded to one oxygen atom, and written as H_2O
water condenser: a glass device for cooling a gas to form a liquid. It is a tube within a tube. The gas flows through the inner tube while water moves through the surrounding outer tube to cool the gas.
water cycle: process of water being reused in the biosphere
water still: a device used to distil water
water vapour: water in the state of a gas when the temperature is less than 100 °C. Water vapour remains in the air as a result of the evaporation of water from the Earth's surface.
weathered: affected by the action of wind, water and weather
weathering: the process of breaking down rocks by conditions in the atmosphere
weight: a measure of the size of the gravity force pulling an object towards the centre of a massive body, such as the Earth. The weight of an object depends on the object's mass.
white blood cells: living cells that fight bacteria and viruses. They are part of the human body's immune system.
wind energy: energy created by wind
wind-pollinated flower: flower that receives pollen carried by the wind from another flower
x-axis: the horizontal axis on a graph
xylem: tissue that carries water and minerals from the roots of plants to all other parts of the plant
y-axis: the vertical axis on a graph

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