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FOR NSW STAGE 4

MELINDA **MESTRE**
LILY **OKATI**
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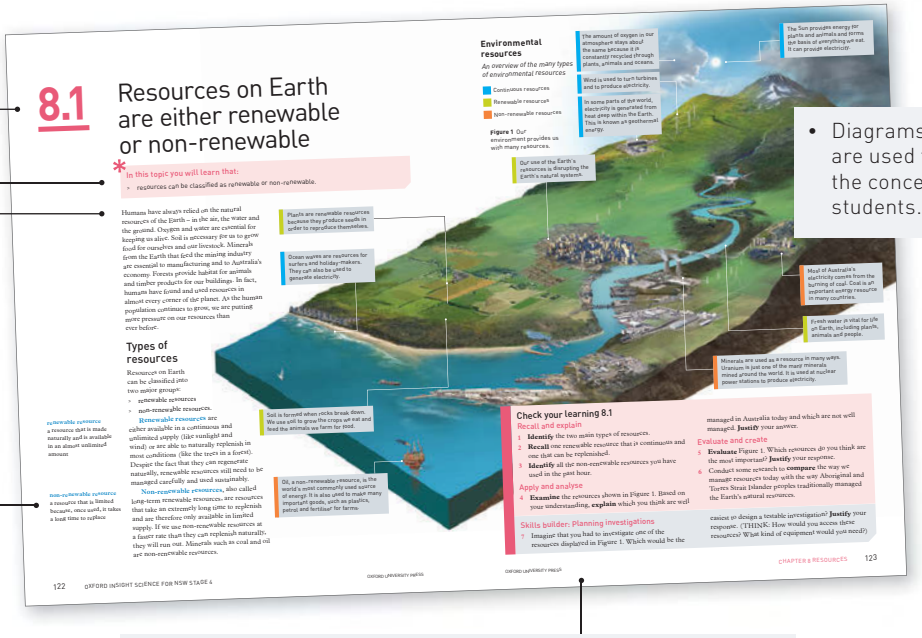
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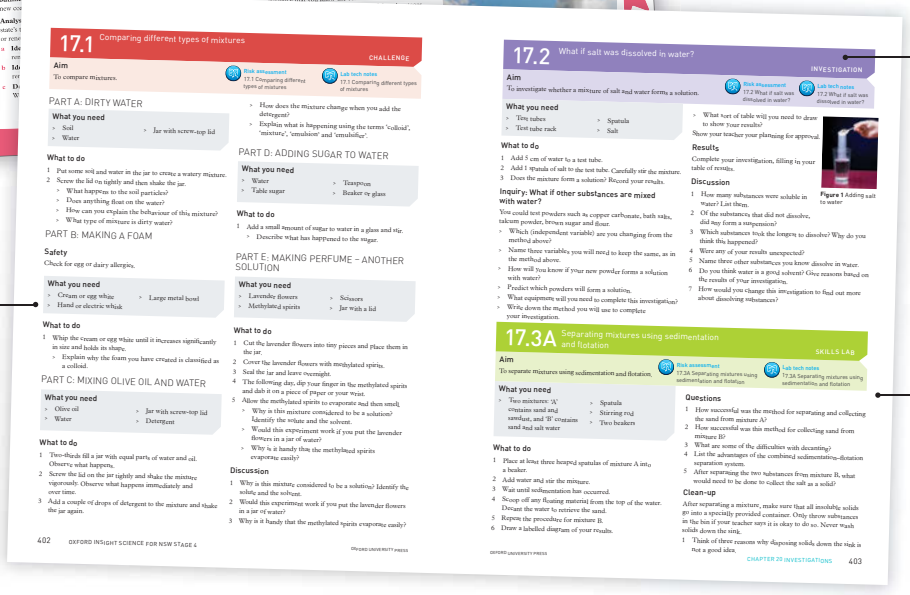
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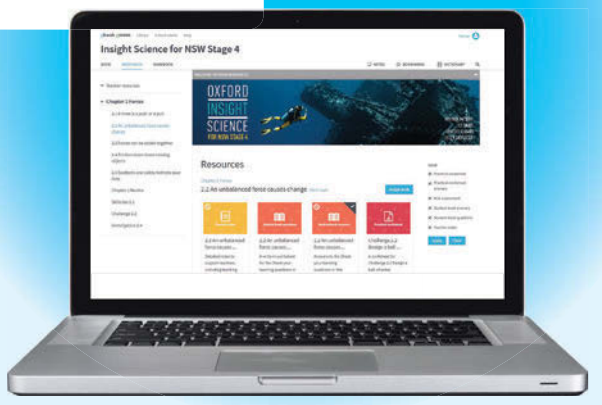
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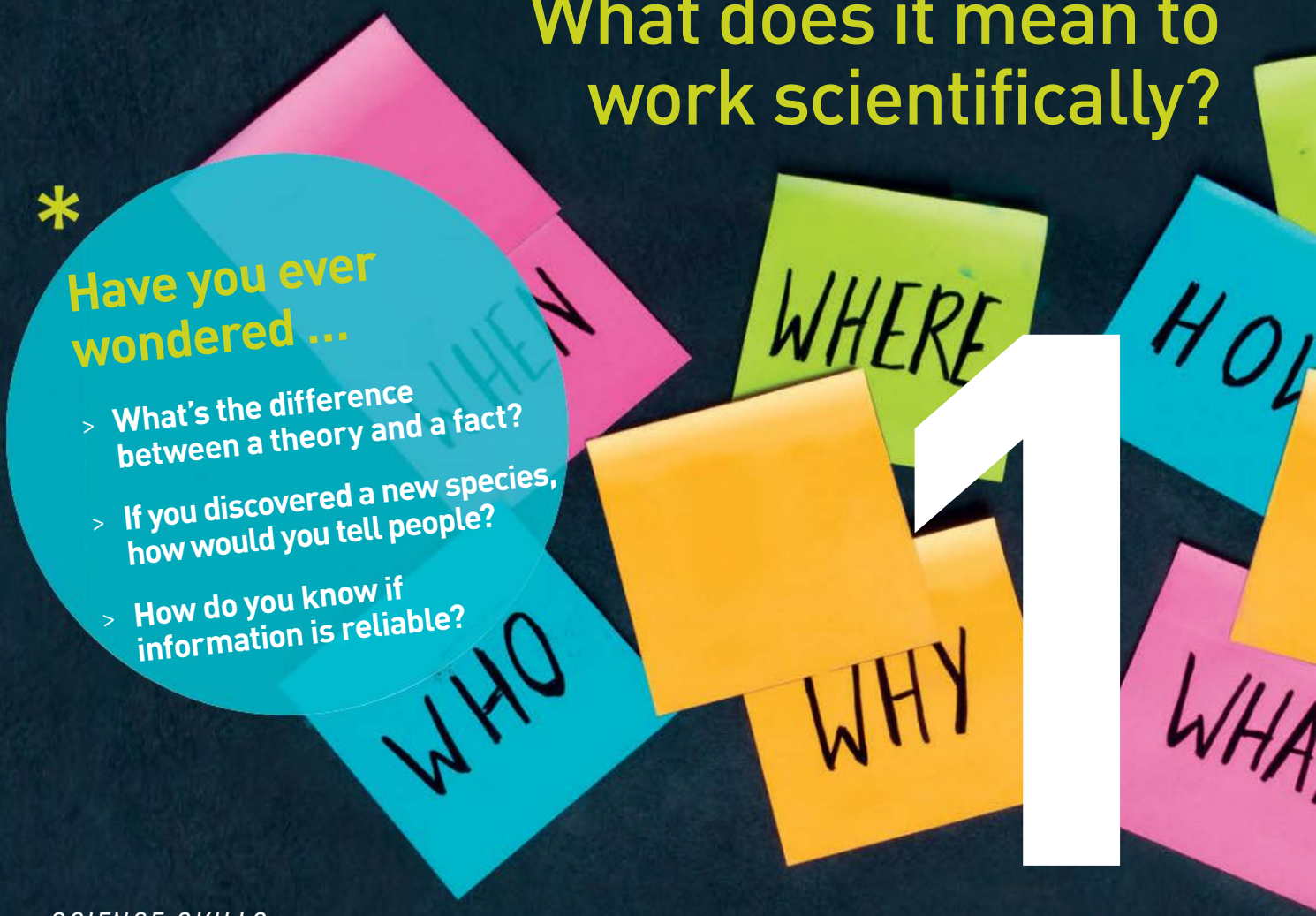
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WORKING SCIENTIFICALLY

What does it mean to work scientifically?



Have you ever wondered ...

- What's the difference between a theory and a fact?
- If you discovered a new species, how would you tell people?
- How do you know if information is reliable?

1

SCIENCE SKILLS

This chapter will help you to practise the six key skills you will need to master throughout Stages 4 and 5 Science. These skills are:

- questioning and predicting
- planning investigations
- conducting investigations
- processing and analysing information and data
- problem solving
- communicating.

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1.1 Scientists ask questions and make predictions

In this topic you will learn that:

- scientific questions can be tested
- scientists make predictions on the outcome of investigations.

scientist
a person who studies the natural and physical world

Science measures what we observe (see, hear, smell and feel) and organises it into testable explanations. **Scientists** have jobs that focus on asking questions and finding answers.

Many scientific discoveries start with one person who is curious about something. Our world would be a very different place without people wondering 'How does this work?' or 'Why is this so?'

Scientists use observation

The skill of observation usually requires you to notice small differences. In Figure 1, there are 10 differences between the two pictures. Can you find them all?

quantitative observation
an observation that uses a number, such as a measurement

Quantitative observations use measurements – they are quantities or amounts and are normally written using numbers. Terms such as 'large', 'small', 'greater than' or 'minimal' may also be used to describe quantitative observations. Numbers are usually accompanied by units, such as 2.7 metres or 23.4°C.

qualitative observation
an observation that uses words and is not based on measurement or other data

Qualitative observations use words to describe anything that isn't an amount. The five sense organs of the human body are essential for qualitative observations. What you see, hear, smell, taste or feel are generally qualitative observations. 'Rough', 'sour' and 'yellow' are all words describing qualitative observations.

Scientists make inferences

inference
a likely explanation of an observation

An **inference** is a likely explanation of an observation. It is how you explain your observation. An inference doesn't necessarily guarantee that something is true, but it is likely to be true. Table 1 contains examples of observations, paired with possible inferences.



Figure 1 Use your observation skills to identify the differences between the two pictures.

Table 1 Some sample observations and inferences

Observation	Inference
Your house smells like cooked onions when you get home from school.	You are probably having cooked onions with dinner.
A fabric feels like satin.	The fabric is either satin or something that feels very much like satin.
You see a man running down the street.	The man is either running away from something or running to something.

SKILLS LAB
1.1: Observation versus inference
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Scientists ask questions

Observations often lead to us asking more questions. For example, you might observe that a can of Coke™ went flat very quickly after opening. Why did this happen? Would a different brand of cola stay fizzier for longer?

Scientists ask questions that they can investigate and find answers by using observation or scientific **experiments**. Scientific questions should also be specific so that it is clear to an outsider what is being tested.

Consider the following questions.

What is the meaning of life?

This is not a good question because it would be hard to test this with observation and scientific tools. Coming up with an answer might also rely on personal opinion, which is not scientific.

What is the best brand of toothpaste?

This is a better question, but what is meant by the word 'best'? It is not clear what the scientist would test from this question.

Do toothpastes with more hydrogen peroxide whiten teeth more than those with less hydrogen peroxide?

This is the best scientific question because it is clear what the scientist wants to discover, and the question can be tested.

A question is considered testable if:

- it is specific
- it can be measured
- it is not based on opinion or research
- you can design an experiment to test the answer.

observation
using all your senses to notice things around you

experiment
an investigation used to solve a problem or find an answer to a question

Making predictions

Once you ask a question, you can predict what may happen. A **prediction** describes the expected result for an investigation. A 'What if' question can be changed into a prediction by removing the 'what' at the start and adding a 'then' at the end of the question; for example: 'What if the amount of vinegar is increased?' (See Figure 2.)

The first half of the prediction is the **independent variable**. A variable is something that can affect the results of an experiment. The second half is what we are testing for. This is called the **dependent variable**.

prediction
the expected result of an experiment

independent variable
a variable that is deliberately changed in an experiment

dependent variable
a variable that may change as a result of the experiment

IF the amount of vinegar is increased, THEN the chemical reaction will occur more quickly.

Independent variable: the variable that is deliberately changed

Dependent variable: the variable that is tested or measured at the end

Figure 2 A prediction describes the expected relationship between the independent variable and the dependent variable. A 'What if' question can be changed into a prediction by removing the 'what' at the start and adding a 'then' at the end of the question.

Check your learning 1.1

Recall and explain

1 **Explain** the term 'observation'. Provide an example.

2 **Identify** the two variables contained in a scientific question.

3 **Explain** how you change a 'What if' question to a hypothesis. Use an example to demonstrate.

Apply and analyse

4 **Classify** the following as inferences or observations.

a You smell a strong odour from a garbage bin.

b Coffee stays hotter if you add the milk before the hot water.

c I measured the temperature today at 37°C.

d It's so hot that the temperature must be 37°C.

e This soup is so hot that it hurts my teeth.

5 **Identify** which of the observations from question 4 are quantitative and which are qualitative.

Evaluate and create

6 **Evaluate** the following scientific questions. What makes them good or bad?

a Is crunchy peanut butter better than smooth peanut butter?

b Is it colder on Jupiter or Saturn?

c How do plants grow?

7 **Propose** better scientific questions to replace those in question 6.

1.2 Scientists plan investigations

In this topic you will learn that:

- reliable experiments are designed to be repeatable
- variables need to be controlled so that only one is tested at a time.

As a scientist you will need to design and plan your own experiments that can be repeated by other scientists. This requires you to control all the variables in the experiment. This is called fair testing.

Control variables

To complete an experiment successfully, you need to control all the factors (also known as variables). A variable is something that can affect the results of an experiment. During an investigation, only one variable should be tested at a time (independent variable). Controlling all other variables ensures that an experiment is fair and that any differences observed are the result of the independent variable on the dependent variable.

fair test
a controlled experiment

Fair tests ensure that experimental results can be used to make the right decisions. When we consider the results of an experiment and try to draw some conclusions, we need to consider the following questions:

- Did we control every factor, except the one we were changing on purpose, so that it was exactly the same?
- Were there any variables in the environment we couldn't control?
- If we did the same experiment again, would we expect the results to be exactly the same?
- Did we estimate any measurements during the experiment?

Make your results reliable

Repetition of experiments is very important. If you were to perform an experiment and achieve certain results, you might conclude that the results were reliable. But what if you did the experiment a second time and the results were slightly different? Did you do something differently? Were the conditions different? Did you use the same materials from the same source?

Performing an experiment several times will give you greater confidence in your results. If other people repeat your experiment and achieve the same results, your results are supported even more.

Use secondary sources

Sometimes the questions we ask already have answers. In these cases, we do not need to design a new experiment because scientists may have already shared this information. Instead, we can find these answers using **secondary sources**.

secondary sources
scholarly books and articles written by authors who did not obtain primary data or evidence first-hand

Activity: Asking 'What if …?'

Consider the following questions.

- What if the amount of vinegar was increased?
- What if the amount of bicarbonate soda was decreased?
- What if the type of vinegar was brown vinegar?

Choose one of the questions above to design an investigation:

a Write a hypothesis for your inquiry.
b What *independent* variable will you change from the first method?
c What *dependent* variable will you measure and/or observe?
d What variables will you need to control to ensure a fair test?
e How will you control them?

SKILLS LAB **1.2:** Controlling an experiment
Go to page **350**.



Figure 1 a A marine biologist observing a sample of algae; **b** a pathologist observing blood samples through a microscope

Secondary sources of information were created by someone who did not experience the experiment first-hand. Sources you could use to find secondary information include:

- websites
- newspaper articles
- reviews
- documentaries
- books.

If you decide to collect information from a secondary source, remember that not all sources are reliable. For example, a government website is more likely to have correct information than a tweet by someone with no science qualifications. Evaluate secondary sources by asking questions such as: Who wrote this? Why did they write this? How old is the information? Where does this information come from?

Check your learning 1.2

Recall and explain

1 **Describe** a variable.
2 **Explain** why most variables need to be controlled.
3 **Identify** the name given to something that is being tested and therefore changed on purpose.

Apply and analyse

4 Justin decided to conduct an experiment to find out whether his cats preferred full-cream or low-fat milk. He gave one cat a saucer of full-cream milk and the other a saucer of low-fat milk; he then left them alone. When he returned an hour later, the low-fat milk was gone and there was a small amount of full-cream milk left. Justin concluded his cats preferred low-fat milk.
   a **Assess** Justin's conclusion. Do you agree?
   b **Analyse** Justin's method. Do you think he conducted a fair test?
   c **Identify** the variables that needed to be controlled. Were they controlled? How could they have affected the results?
   d **Propose** an improvement to Justin's experiment to make his results more reliable.

Evaluate and create

5 Consider the following claims and **justify** why you would investigate these claims by designing an experiment either to collect first-hand information or by using secondary sources to find information.
   a Climate change is caused by humans.
   b A person's height changes throughout the day.
   c The Moon is made of cheese.

1.3 Scientists conduct investigations safely

In this topic you will learn that:

- scientists follow safety rules to minimise danger in experiments.

Scientists may be exposed to a variety of hazards in their work. In unfamiliar environments, such as out in the field, there are many safety hazards they cannot control. In a **laboratory**, safety issues are easier to manage.

laboratory
a specially designed space for conducting research and experiments

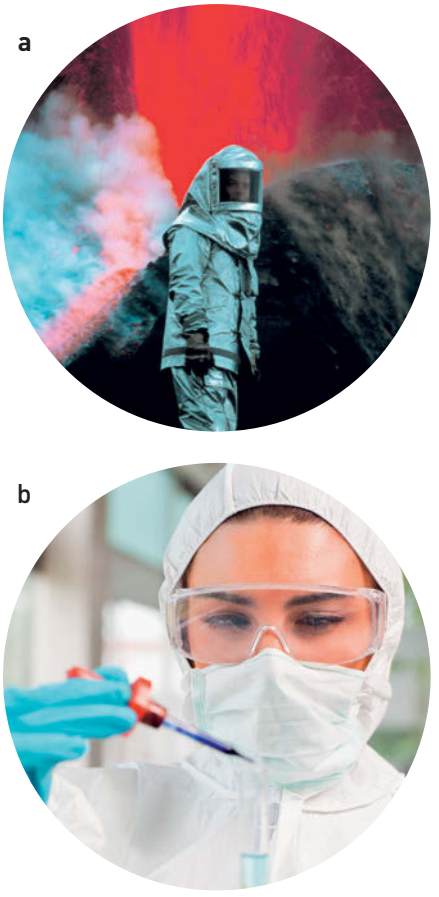


Figure 1 a Vulcanologists (scientists who study volcanoes) wear amazing heat-resistant silver suits to protect themselves against heat, ash and molten rock. **b** Microbiologists researching infectious diseases wear protective clothing to ensure they don't get sick.

Video
The science lab tour

Laboratory safety

As a science student, just like every scientist, it is your responsibility to be familiar with your laboratory, including where the safety equipment is located, what the warning signs mean and what to do in an emergency. Most safety is common sense – common sense can prevent many dangerous situations.

Safety symbols

Safety symbols are used in many different settings. You may have seen the ones in Figure 2 on building sites, at entrances to buildings, at school or on roads. Your laboratory may already have some of these symbols displayed.

Symbols are often simple drawings, although sometimes words are also used. If a picture can show a message clearly, words may not be needed.

Laboratory safety rules

A class laboratory is not like a normal classroom – there are additional rules to follow. The class laboratory is a place where people are learning to be better scientists, but they may not always get it right the first time. You will notice your science skills improving as you do more and more experiments carefully in the laboratory.

Below is a list of dos and don'ts for the science laboratory. Can you give a reason why each of these rules is important to follow in a lab?

Do:

- wear a lab coat for practical work
- keep your workbooks and paper away from heating equipment, chemicals and flames
- tie long hair back whenever you do an experiment
- wear safety glasses while mixing or heating substances
- tell your teacher immediately if you cut or burn yourself
- tell your teacher immediately if you break any glassware or spill chemicals
- wash your hands after any experiments
- listen to and follow the teacher's instructions
- wear gloves when your teacher instructs you to.



Figure 2 What does each of these symbols mean?

Don't:

- run in a laboratory
- push others or behave roughly in a laboratory
- eat in a laboratory
- drink from glassware or laboratory taps
- look down into a container or point it at a neighbour when heating or mixing chemicals
- smell gases or mixtures of chemicals directly; instead, waft them near your nose and only when instructed
- mix chemicals at random
- put matches, paper or other substances down the sink
- carry large bottles by the neck
- enter a preparation room without your teacher's permission.

Creating laboratory safety rules

How many potentially dangerous activities can you identify in Figure 3?

- What rules might be needed to prevent potential danger?



Figure 3 Can you see the potentially dangerous activities?

- Create a list of rules you think might be needed in your science laboratory. Give a possible consequence if each rule is not followed.
- Compare your list of rules with the dos and don'ts tips listed above.
- Type up your list on a computer, print it out and stick it on the inside front cover of your workbook.

Check your learning 1.3

Recall and explain

1 a **Identify** three items of protective clothing you might wear in the laboratory.

b **Explain** why you should wear each of them.

2 **Identify** five things you should do to remain safe in the laboratory.

Evaluate and create

3 **Identify** five things you shouldn't do in the laboratory.

4 Mae wants to investigate the speed of ice melting at different temperatures. She uses ice cubes from her freezer at home, and places them directly on her kitchen bench in two piles. Mae starts by pouring some lukewarm water over the first pile of ice cubes, and watches as they begin to melt slowly. Mae then boils a kettle and pours the scalding water over the ice cubes on the bench. She observes they melt a lot faster.

Evaluate the safety of Mae's method. What would you change to make her investigation safer?

5 **Evaluate** Figure 4. Write down as many science dos and don'ts that you can find.



Figure 4 Science dos and don'ts

1.4 Scientists use equipment

*

In this topic, you will learn that:

- scientists use specialised equipment to conduct experiments in the laboratory and in the field
- scientists record their experiment set-up by drawing scientific diagrams.

equipment
items used in the laboratory to conduct experiments

scientific diagram
a clear, side view, labelled drawings made using a sharp pencil

apparatus
equipment placed together for an experiment

Bunsen burner
used as a heat source in the laboratory

Scientific equipment

Equipment is the name given to the beakers, burners, flasks, stands and other items used by scientists to conduct experiments. Using the correct equipment ensures accurate results and the safety of the scientist.

Commonly used equipment is shown in Figure 1. Some of the names may sound unfamiliar, but you will soon learn what each piece of equipment is called and how it is used. The equipment in your school laboratory may look slightly different because each laboratory has its own type of equipment. Some items of equipment can be used together in an experiment. Equipment placed together for an experiment is called an **apparatus**.

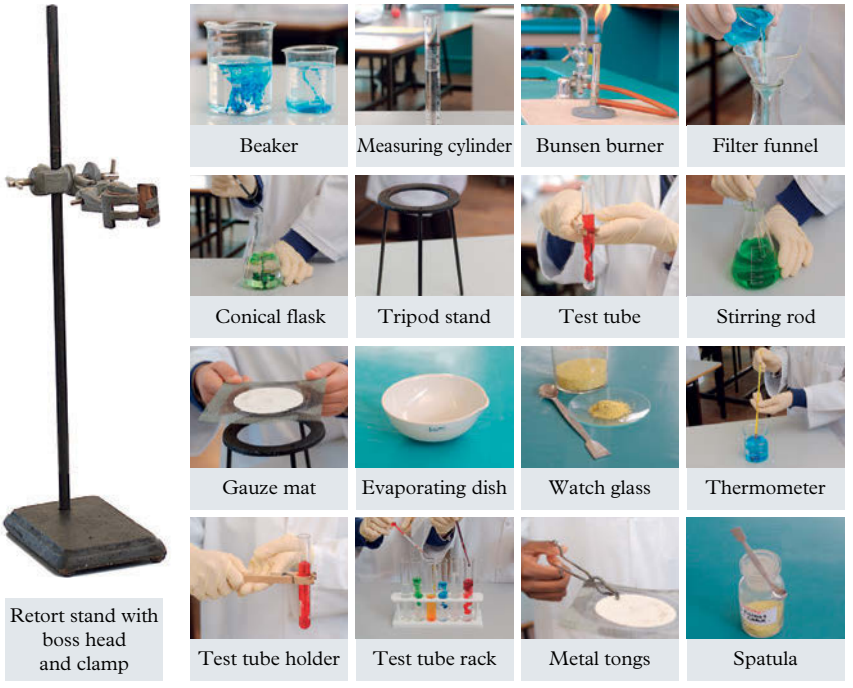


Figure 1 Types of equipment used in the laboratory

Scientific diagrams

To show others how to set up an experiment, scientists write a list of equipment needed and provide a drawing of how the equipment should be set up.

Scientists have a quick and simple way to show scientific equipment. They use drawings called **scientific diagrams**. Using scientific diagrams means you don't have to be an artist to be a good scientist and you have more time to do the experiments.

The procedure for drawing scientific diagrams is as follows:

1. Draw clearly and neatly.
2. Use a sharp grey pencil.
3. Draw the equipment from the side view.
4. Don't show any detail, just a simple outline with no shading.
5. Draw lines using a ruler.
6. Print labels neatly and connect them to the diagram with a line or arrow.
7. Spell labels correctly. Incorrect spelling makes good science look bad!
8. Diagrams should be between 6 and 10 centimetres high.

Bunsen burners

A Bunsen burner is one of the most useful pieces of equipment in the laboratory. The **Bunsen burner** is used to heat things in the laboratory, so it needs to be hot. Under the right conditions, the hottest part of a Bunsen burner flame can be over 1500°C.

The Bunsen burner has a collar that can be turned to open or close the air hole. The position of the collar controls how much air enters the burner and therefore how hot the

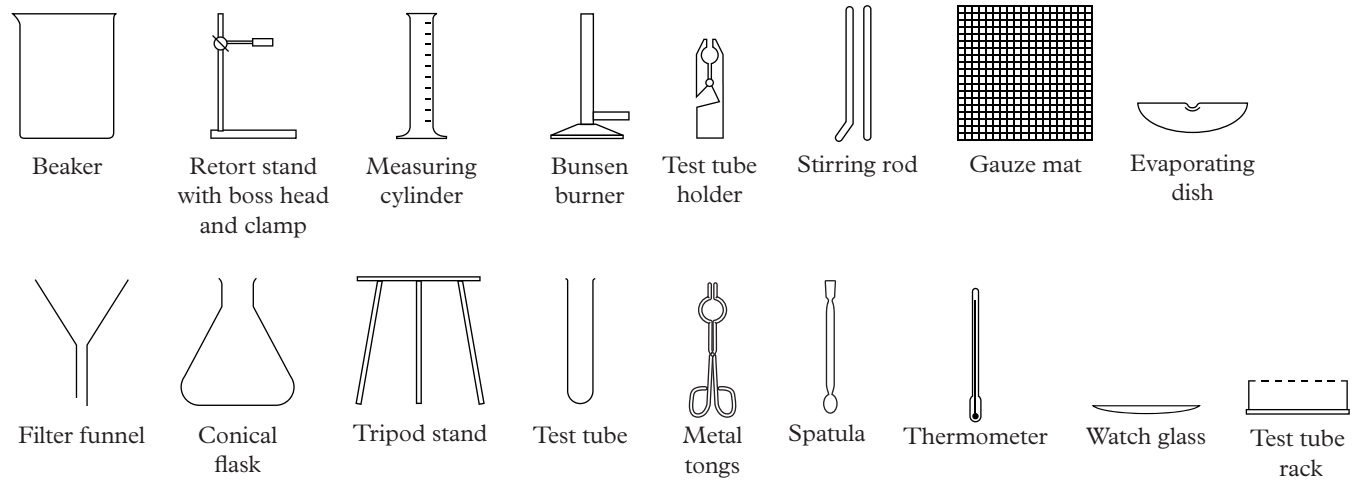


Figure 2 Scientific drawings of laboratory equipment

flame is. If the hole is closed, less air can mix with the gas. This results in a yellow safety flame (see Figure 4). If the collar hole is open, air mixes with the gas, allowing a hotter blue flame to burn.

When alight but not being used for heating, the Bunsen burner should be left on the yellow (safety) flame, which is not as hot and is easy to see. The safety flame is always used when lighting the burner. A Bunsen burner is a hazardous piece of equipment. Before you use one, you should understand the risks involved and what to do in case of a fire in the laboratory. If something goes wrong, always tell your teacher first. If someone gets burned, quickly run the skin under a cold tap for at least 15 minutes and seek medical attention if necessary.

Interactive
Types of equipment used in the lab

Video
Test tube skills

Video
How to use a Bunsen burner

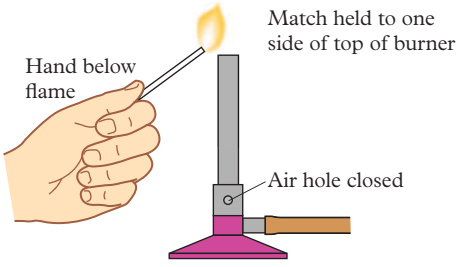


Figure 3 The right way to light a Bunsen burner

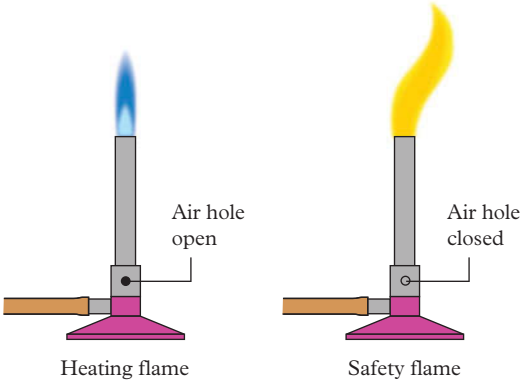


Figure 4 Blue (heating) and yellow (safety) flames on the Bunsen burner

Check your learning 1.4

Recall and explain

1 **Construct** a scientific diagram for each piece of laboratory equipment listed below.
   - **a** Filter funnel
   - **b** Beaker
   - **c** Metal tongs
   - **d** Measuring cylinder

2 **Recall** the colour of the Bunsen burner's safety flame.

3 **Recall** the colour of the Bunsen burner's heating flame.

4 **Explain** how you get a heating flame with your Bunsen burner.

5 **Explain** how you should treat a scald.

Apply and analyse

6 **Identify** what equipment you would use to safely perform the following tasks.
   - **a** Measure 20 millilitres of water
   - **b** Stir a mixture in a beaker
   - **c** Measure the temperature of a liquid in a test tube
   - **d** Pick up a hot test tube

1.5 Scientists conduct investigations with accuracy

In this topic you will learn that:

- scientists use different units of measurement for length, mass, time, temperature and volume
- scientists need to record measurements accurately to make sure their results are reliable.

unit
a standard measurement

metric system
a system of measurement

Whether you are always aware of it or not, you use measurements every day. You may buy milk in a 1 litre carton and ask for 200 grams of ham at the supermarket. You might walk 800 metres to school each day. If you are ill, a doctor will measure your body temperature to see if it varies from the normal 37°C. Each time you look at your watch, you are measuring time. Measurements are, and have always been, an important part of life and science.

Measurements and units

In the past, measurements could be based on the length of a step or the size of a hand. But using human body parts for basic measurements caused confusion and arguments because everyone's body size is different. So many different systems were being used to measure things that people were often cheated, such as when buying goods by weight.

In 1790, the King of France, Louis XVI, decided that, in his country at least, a uniform system should be established. In 1791, a committee was set up to find a new system. This was ultimately called the metric system, from the Greek word *metron*, meaning 'to measure'.

The idea of having standard **units** for measurement soon spread, so all types of measurement were included. The **metric system** is now used by scientists worldwide. A measurement of 2.45 metres has to be the same in Wonthaggi, Victoria, as in New York, USA. A temperature of 37°C is just as hot in Kolkata, India, as in Kyabram, Victoria. Scientists often check one another's work by repeating experiments to see if they get the same results. To do this, they need to be able to use measurements that are the same as those of the original experiment. Using a standard system of measurement, scientists everywhere can understand and build on one another's work.

Five kinds of measurements are important when you are exploring science: volume, mass, temperature, time and length.

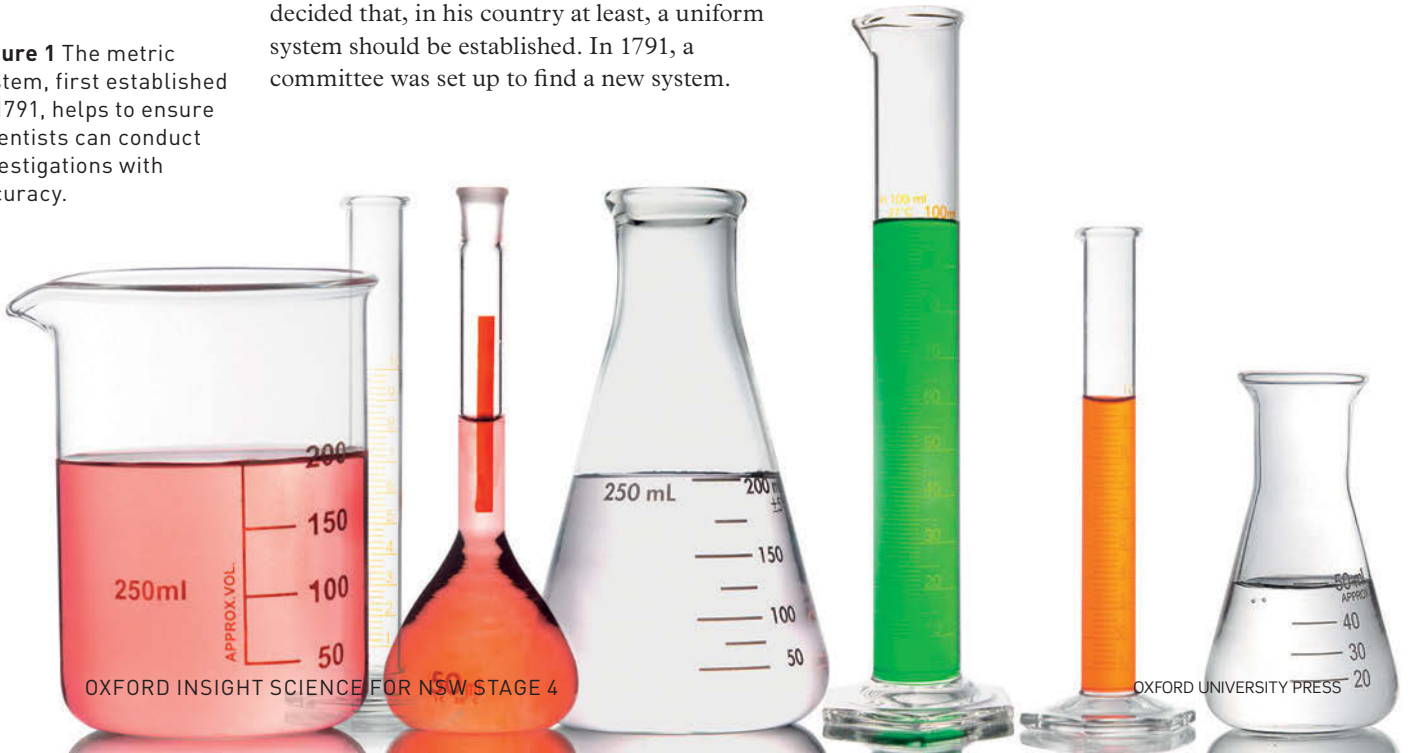


Figure 1 The metric system, first established in 1791, helps to ensure scientists can conduct investigations with accuracy.

SKILLS LAB
1.5: Measuring mass and volume
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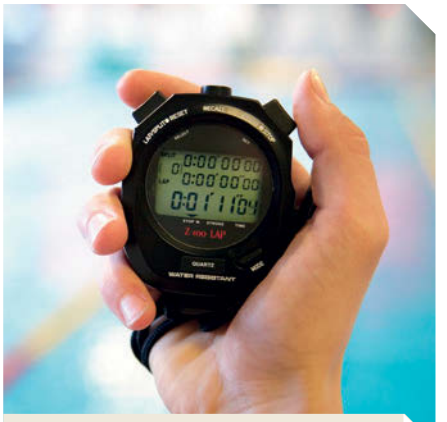
LENGTH

Figure 2 Measurements of length can be shown using a unit called metres, with the symbol 'm'. For long distances, kilometres (km) are used. For short distances, centimetres (cm) or millimetres (mm) can be used. In school science, the devices we use to measure length and distance include the trundle wheel (pictured), metre rule and tape measure.



MASS

Figure 3 Mass is the amount of matter or substance in an object. It is measured in units called grams (g), kilograms (kg) and tonnes (t). Smaller masses are measured in milligrams (mg). Mass-measuring devices are called scales or balances. You will use an electronic balance to measure mass.



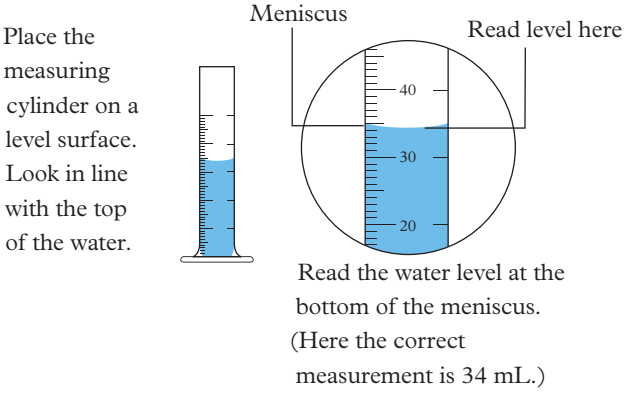
TIME

Figure 4 Time is measured with a watch or clock. A watch or clock set to the correct time tells you the time of day. A stopwatch measures how much time has passed. In your experiments, measurements of time will often have the unit called seconds (s).



TEMPERATURE

Figure 5 Temperature is measured using a thermometer. Some thermometers have a digital scale. Measurements of temperature have the unit called degrees Celsius. Its symbol is '°C'.



VOLUME

Figure 6 Volume is how much space something takes up. Measurements of liquid volumes can be shown with units called litres (L) or millilitres (mL). In science, beakers and measuring cylinders are used to measure the volume of liquids. Some beakers have a measuring scale on them, but measuring cylinders are more accurate than beakers. Scientists usually prefer to use measuring cylinders to measure volume. Measurements of the volume of solid objects have units such as centimetres cubed (cm^3). The diagram above shows how to read from a meniscus in a measuring cylinder.

Recording measurements

All measurements have two parts: a number and a unit. For example, 5 metres is written as '5 m'. Notice that the unit does not have an 's' after it, even though it stands for 'metres'.

Measurements are usually recorded in a table or a graph so that they can be easily read, compared or used for further calculations.

Table 1 Some metric units of measurement

Measurement	Unit	Symbol	Instrument used
Distance or length	Kilometre	km	Trundle wheel
	Metre	m	Metre rule
	Centimetre	cm	30 cm ruler
	Millimetre	mm	30 cm ruler
Volume	Litre	L	Beaker
	Millilitre	mL	Measuring cylinder
Mass	Tonne	T	Weighbridge
	Kilogram	kg	Beam balance
	Gram	g	Spring balance
	Milligram	mg	Electronic scales
Time	Hour	h	Clock
	Minute	m	Stopwatch
	Second	s	Stopwatch
Temperature	Degrees Celsius	°C	Thermometer

Video
Measurement, errors and accuracy

accuracy
careful, correct and consistent measurement or processing of data

Converting units of length

To compare two measurements, their units must be the same. It is difficult to compare 10000 metres with 13 kilometres – which is longer? Comparing 10 kilometres with 13 kilometres is much easier. The metric system works in multiples of 10, so we can convert using a formula:

1 kilometre = 1000 metres

1 metre = 100 centimetres

1 centimetre = 10 millimetres

- To change a larger unit (such as kilometres) into a smaller unit (metres), you need to multiply.
- To change a smaller unit (such as millimetres) into a larger unit (centimetres), you need to divide.

Table 2 Converting units

Change from	Change to	Conversion
km	m	× 1000
m	cm	× 100
cm	mm	× 10
m	km	÷ 1000
cm	m	÷ 100
mm	cm	÷ 10

Worked example

Which is longer: 150 metres or 12 000 centimetres?

Solution

Change m to cm (× 100).

150 m × 100 = 15 000 cm

Therefore, 150 metres is longer than 12 000 centimetres.

Measuring accurately

Accurate measurement in science is important so that your results are a true record of something. Comparing measurements with other scientists is useful only if your results are accurate.

You can do several things to improve your **accuracy** in the science laboratory; for example:

- Always take your time when measuring and make sure you write down the result straight away.

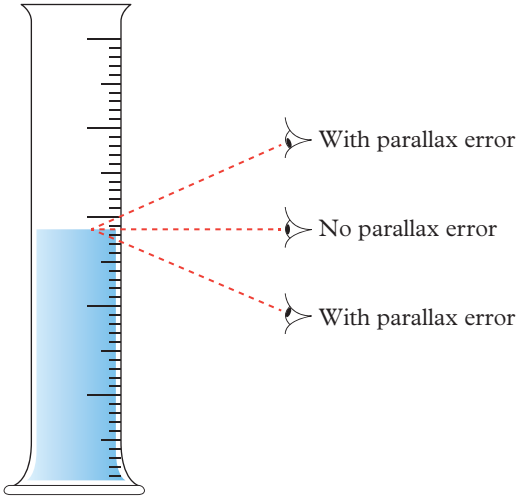


Figure 7 Parallax error occurs when you read a scale from an angle.

- When reading a scale, line up your eye directly in front of the object and the scale. Looking from above or from the side can produce different readings. This is called **parallax error**.

Sometimes errors in measurement are unavoidable. An **error** is different from a mistake – it can happen for various reasons, no matter how careful you are. Errors can occur if the object you are measuring falls between two markings on a scale. This will mean that you have to estimate the exact measurement. Sometimes scales can be calibrated (set up) incorrectly, which means that no matter what you measure you will get a slightly inaccurate result. You can minimise the effect of this kind of error by always using the same measuring device.

Understanding accuracy, validity and reliability

When collecting and evaluating data, you may be asked to assess the data or investigation in terms of three things: accuracy, validity and reliability.

As we've discussed already, accuracy refers to the precision of measurements taken during an investigation.

The validity of an investigation is based on whether or not the method used to test a question is appropriate. If your results measure something other than what you intended, your investigation is not valid. For example, if a student used a ruler to measure the temperature of a drink, this would not be a valid investigation because a ruler is used to measure length, not temperature. If a thermometer was used, the investigation would be valid.

The reliability of a first-hand investigation can be assessed based on whether or not the results or outcome of the investigation can be repeated more than once. If you repeat an investigation many times, and receive the same result (or at least close to the same result), the investigation is considered reliable. However, if you get drastically different results each time you repeat the experiment, the investigation and data are not reliable.

The reliability of a secondary source asks how trustworthy the source is. You can assess the reliability of the source by asking:

- who the author is (what are their qualifications?)
- where the source was published (such as a blog or a government website)
- when the source was written (is it out of date?)
- if it refers to a valid investigation.

parallax error
an error that occurs when reading a scale from an angle

error
the unavoidable and random inconsistency in measurement



Resource
STEM activity: Walk the line

Check your learning 1.5

Recall and explain

1. List everything you have measured today. Think carefully – you have probably measured more things than you realise. **Identify** at least five things.
2. **Explain** why it is a problem to use body parts as a measuring tool.
3. **Describe** a meniscus.
4. **Recall** which part of the meniscus is used when measuring volume.

Apply and analyse

5. **Compare** a walk that is 14 900 centimetres with a walk that is 3 kilometres. Which is longer?
6. **Identify** what tools you would use to measure the following things.
   - a. Distance around a cricket ground
   - b. Time it takes a sprinter to run 100 metres
   - c. Mass of a carrot
   - d. Volume of water in a fish tank
   - e. Volume of a square block
   - f. Temperature of a swimming pool
   - g. Your mass
   - h. Thickness of this book
7. **Calculate** which is longer: 10 000 millimetres or 500 metres.
8. **Calculate** which is shorter: 3 kilometres or 1000 metres.
9. **Convert** 1 kilometre into metres, centimetres and millimetres.

Evaluate and create

10. In the United States, people use imperial units of measurement (foot, pound, mile), but American scientists use metric units. **Propose** a reason to explain why scientists do this.

1.6 Scientists keep a logbook

*

In this topic you will learn that:

- data can be represented in a range of ways, including graphs, tables, models and diagrams.

logbook
a record of the details of the work carried out in a science laboratory

A science **logbook** is used to record the details of the work done in a science laboratory. It contains information that the scientist may otherwise forget and provides evidence of the planning, changes and results of an experiment.

Basic rules for keeping logbooks

There are some basic rules to creating and using a logbook:

1. Use a bound notebook or an electronic device that is backed up regularly. Loose papers become lost, and electric devices can fail. Ensure that the style of records you use are reliable.
2. Label your logbook with your name, phone number, email address, school and teacher's name. Logbooks can become lost. Labelling the logbook with your contact details (and those of your school and teacher) ensures that it will find its way back to you.
3. The second page of the logbook should contain a table of contents. Each page should be numbered to help you find the relevant experiments.

Table 1 A logbook's table of contents

Unit/subject	Experiment title	Page number

4. Always date every entry.

Check your learning 1.6

Recall and explain

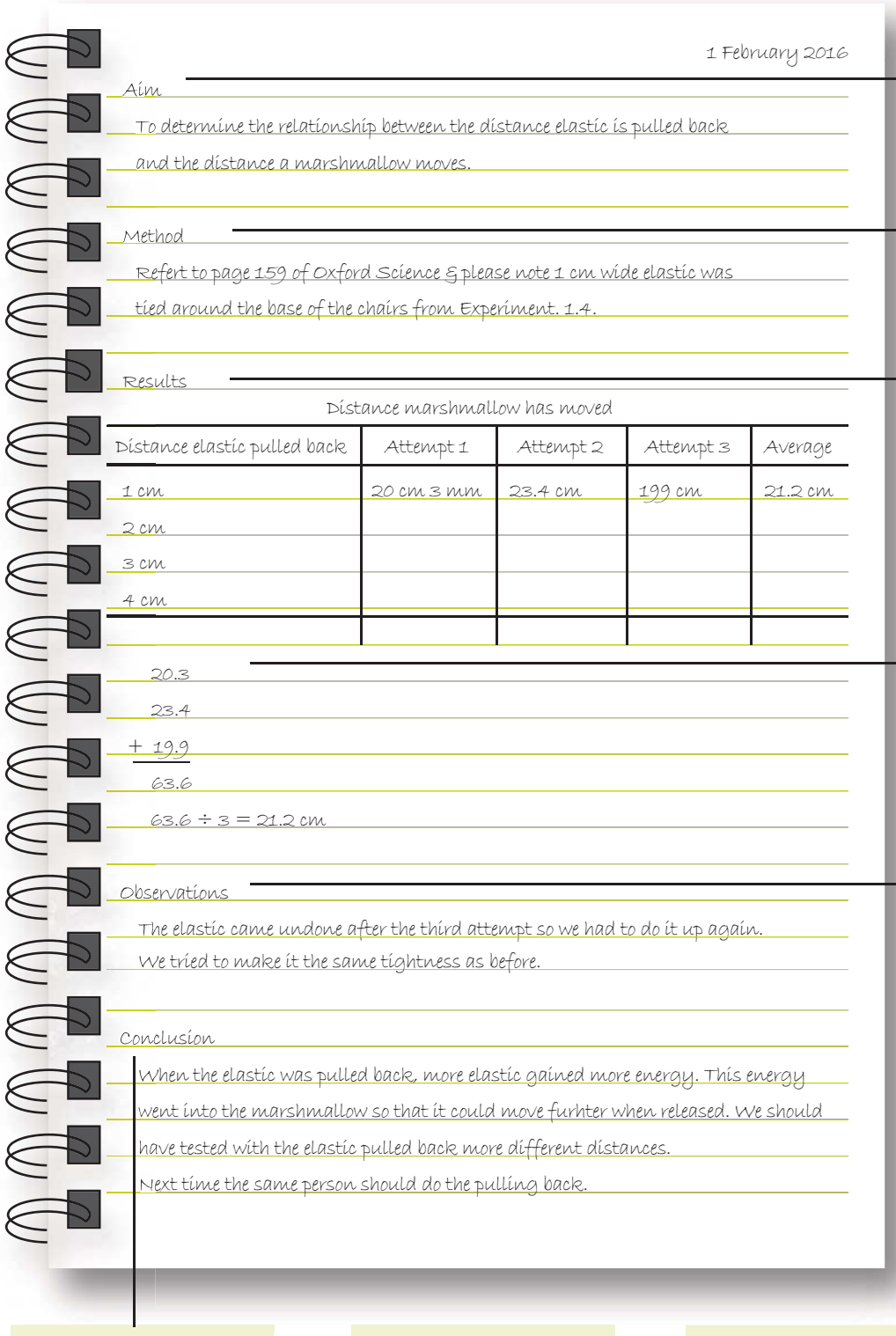
1. **Explain** the purpose of a laboratory logbook.
2. **Explain** why it is important to make sure the writing in your logbook is legible.
3. **Explain** why you should reflect on each experiment before starting the next experiment.

Apply and analyse

4. **Contrast** a logbook with a formal science report.
5. **Propose** one reason why it is important to include the date of the experiment in the logbook.
6. A student made a mistake and ripped the page out of their logbook. **Discuss** why this would be the wrong thing to do.



Figure 1 A scientist recording details in a logbook



1 February 2016

Aim

To determine the relationship between the distance elastic is pulled back and the distance a marshmallow moves.

Method

Refert to page 159 of Oxford Science 8 please note 1 cm wide elastic was tied around the base of the chairs from Experiment. 1.4.

Results

Distance marshmallow has moved

Distance elastic pulled back	Attempt 1	Attempt 2	Attempt 3	Average
1 cm	20 cm 3 mm	23.4 cm	199 cm	21.2 cm
2 cm				
3 cm				
4 cm				

20.3
23.4
+ 19.9
63.6
63.6 ÷ 3 = 21.2 cm

Observations

The elastic came undone after the third attempt so we had to do it up again. We tried to make it the same tightness as before.

Conclusion

When the elastic was pulled back, more elastic gained more energy. This energy went into the marshmallow so that it could move furhter when released. We should have tested with the elastic pulled back more different distances. Next time the same person should do the pulling back.

Aim and hypothesis of the experiment.

The method used or the page number of the method. Record any changes to the method.

Record any measurements you made to the maximum number of digits provided by the equipment. (You can round them off later. If you don't record them, you cannot get them back later.)

Show all calculations (even when adding simple numbers).

Include any ideas, explanations, diagrams, graphs, sketches or mistakes that happened. Write everything down, even if it seems unimportant. You may not remember it weeks or even months later.

Do not rewrite any entries. Try to keep it as neat as you can, but it is not a formal report. It is more important that you record your data and observations; if you make a mistake, put a single line through it. Do not white it out as it may be useful again later.

Include a conclusion or reflection for each experiment to make sure you understood why you got the results you did.

You may need to write up a formal report for your experiment. If you have completed your logbook well, you will find all the details of the report easily available.

Glue or staple in any photocopies to prevent them falling out.

Figure 2 A laboratory logbook

1.7 Scientists process and analyse information

In this topic you will learn that:

- data can be represented in a range of ways, including graphs, tables, models and diagrams
- inferences can be made by interpreting data sets.

column graph
a graph in which the height of the columns represents the number measured

continuous data
data where the numbers can be any value

scatter graph
a graph used to represent continuous data; it consists of discrete data points

Scientists process their data from first-hand investigations and secondary sources so that it is easier to understand. They can then analyse this data to identity trends, patterns and relationships that may help to answer their scientific questions.

Data tables

When recording the results of your experiments, the data you collect should be neatly presented in a table. There are four steps for drawing up a table:

1. Use a ruler to draw up a table with the correct number of columns.
2. Write a table heading that describes the content of the table, such as 'The change in water temperature over time'.
3. Give each column a label and units (what the number means), such as 'Temperature (°C)'. The variable being changed (independent variable) goes in the first column, and the variable being measured (dependent variable) goes in the columns to the right.
4. Add your data in the correct columns.

Table 1 Change in water temperature over time

Temperature (C°)	Time (min)
43	5
37	10
35	15
24	20

Figure 1 A sample table showing heading, column headings with units of measurement, and data in each column.

Discrete and continuous data

discrete data
data where the numbers can only be whole numbers

There are two main types of data: discrete and continuous. **Discrete data** is when the numbers can only be whole numbers, such as the number of people in a class (you can't have half a person). Discrete data is often represented in a **column graph**.

Continuous data is when the numbers can be any value. For example, the tallest person in the world is 551 centimetres tall; the fastest time in the world for a 100 metre race is 9.58 seconds. Continuous data should always be represented in a line or **scatter graph**.



Figure 2 Sultan Kosen is 551 centimetres tall. Usain Bolt ran 100 metres in 9.58 seconds. Height and time are examples of continuous data.

Common features in graphs

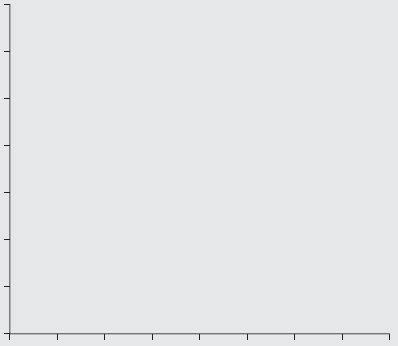
There are four features all graphs have in common:

1. a descriptive title of what the graph shows
2. a grid that is used to plot the points or data
3. the independent variable on the horizontal axis
4. the dependent variable on the vertical axis.

The independent variable should be on the horizontal axis, and the dependent variable should be on the vertical axis. Units should be included in parentheses when relevant.

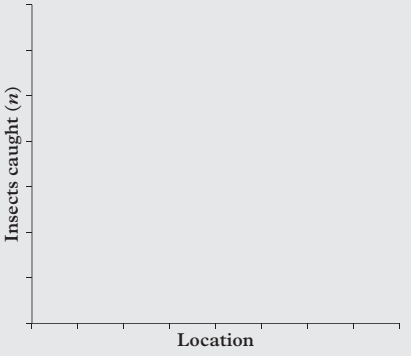
Drawing column graphs

In a column graph, the height of the columns shows the number that you were measuring. This type of graph is good for showing discrete data. The steps for drawing a column graph are listed below.



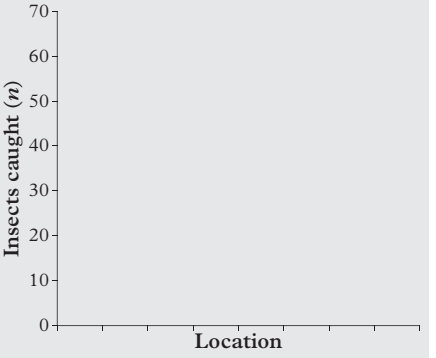
STEP 1

Use a pencil and a ruler to draw a large set of axes (the horizontal and vertical lines of a graph).



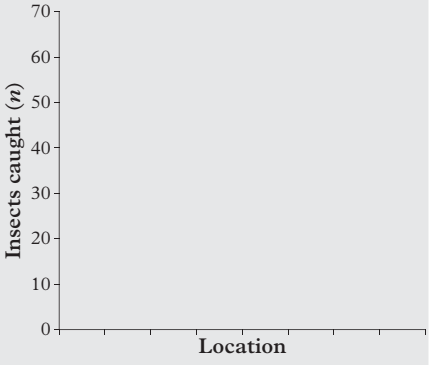
STEP 2

Label each axis. The horizontal (flat) axis should show the independent variable, and the vertical (up) axis should be the dependent variable. For example, when graphing the number of insects found at each location, the location is changed and the number of insects is counted at each point. Therefore, location is the independent variable and is on the horizontal axis. The number of insects is the dependent variable and is on the vertical axis.



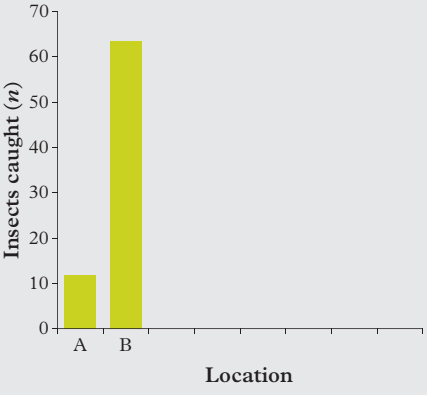
STEP 3

Add numbers at regular intervals to the vertical axis, making sure you will fit the largest number. If the numbers are small, spread them out to use the whole graph.



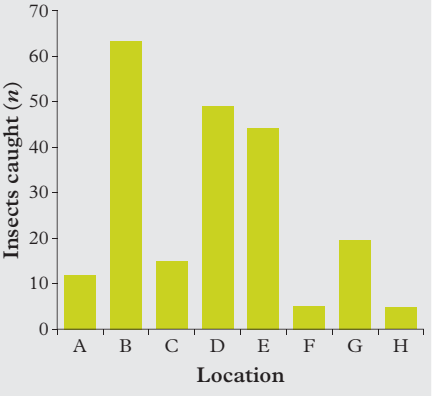
STEP 4

Add units (what the numbers mean) to the axis. This is usually metres (m), minutes (min) and seconds (s), but can be also the number (*n*) of things.



STEP 5

Plot your data on the graph. Rule the lines carefully, making sure there is a gap between the columns.



STEP 6

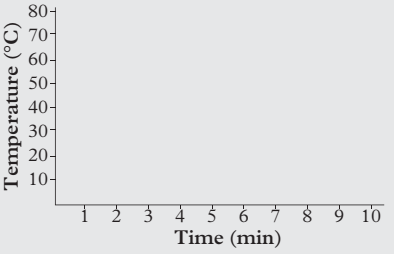
A completed column graph showing the number of insects caught at different locations.

Drawing scatter graphs



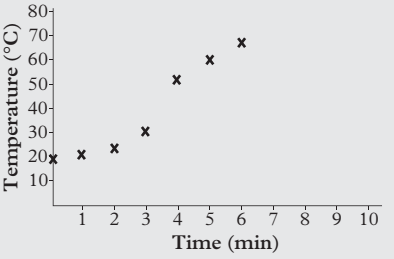
STEP 1

Use a pencil and a ruler to draw a large set of axes (the horizontal and vertical lines of a graph). Label each axis. The horizontal (flat) axis should show the independent variable, and the vertical (up) axis should be the dependent variable. For example, when graphing how temperature changes over time, the time is changed and the temperature is measured as a result. Therefore, time is on the horizontal axis and temperature is on the vertical axis.



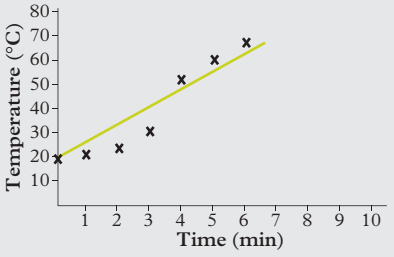
STEP 2

Add numbers at regular intervals to the axes, making sure you fit the largest number. If the numbers are small, spread them out to use the whole graph. Add units (what the numbers mean) to the axes.



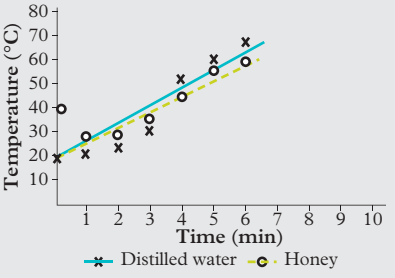
STEP 3

Plot your data on the graph. Use small crosses rather than dots. It is easier to find the centre of a cross than the centre of a dot.



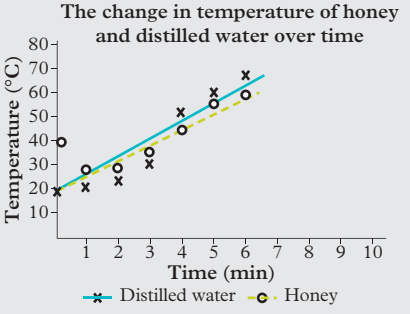
STEP 4

Draw a **line of best fit** or a smooth curve that passes through or near to as many data points as possible. In this case a line of best fit is shown.



STEP 5

If you are plotting more than one set of data on the one graph, then use a small circle instead of a cross. Add a legend to help identify which set of data is which.



STEP 6

Write a descriptive title at the top of the graph.

line of best fit
the line on a scatter graph that passes through, or as near to, as many data points as possible

Interpreting graphs

Line graphs are the most common graphs that are drawn in scientific reports. These graphs are used to show the relationship between the independent variable and the dependent variable. The shape of the graph gives a hint of how the two variables are related.

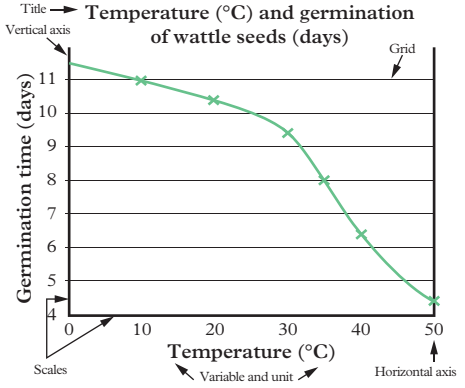


Figure 3 A line graph of germination time of wattle seeds versus temperature

When the line slopes upwards, this means the dependent variable increases as the independent variable increases. This is called a directly proportional relationship.

When the line is horizontal, it means the dependent variable is not affected by the independent variable.

If the line is sloped down, the dependent variable decreases as the independent variable increases. This is called an inversely proportional relationship.

Occasionally a graph is curved. These types of graphs should be divided into sections. Section A (between 1 and 4 of Figure 4) shows a directly proportional relationship. Section B (between 4 and 7) shows an inversely proportional relationship.

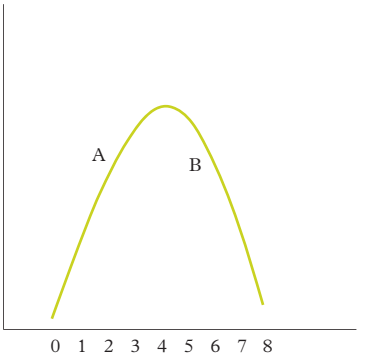


Figure 4 A curved graph is divided into sections.

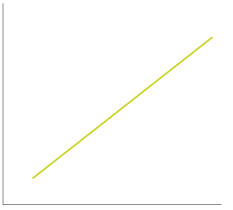


Figure 5 A directly proportional relationship

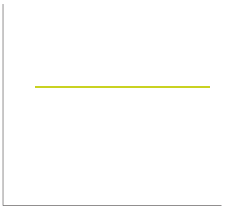


Figure 6 When the dependent variable is not affected by the independent variable

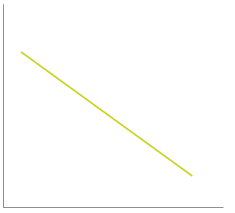


Figure 7 An inversely proportional relationship

Check your learning 1.7

Recall and explain

1 **Identify** the two types of quantitative data that scientists collect.

2 **Recall** which variable should be located on the horizontal axis of a graph.

3 **Explain** why graphs are often used in scientific reports.

Apply and analyse

4 Figure 8 shows a graph drawn by a student. **Identify** all the things that should be corrected on the graph.

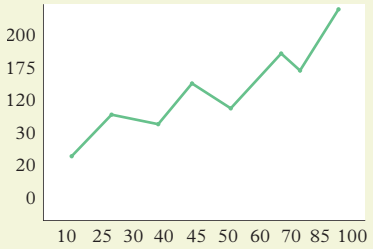


Figure 8 Graph drawn by a student

5 **Describe** the relationship between the independent variable and dependent variable in Figure 9.

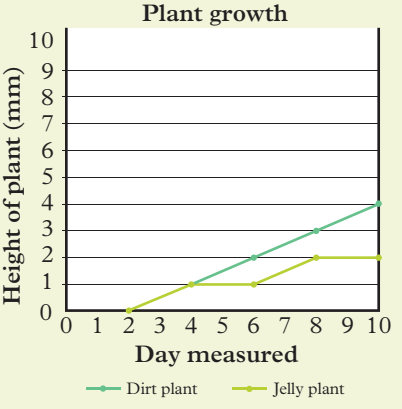


Figure 9 Height of plant versus day measured

6 a **Construct** a graph to show the data.

b **Explain** what has happened during each event.

Month	Number of accidents
January	0
February	10
March	6
April	3
May	2
June	1

1.8 Scientists solve problems

In this topic you will learn that:

- scientists identify problems and suggest solutions based on knowledge and discoveries.

In this chapter you have learnt about asking questions and doing science safely. You have used your skills of experimentation, observation, inference and measurement. You are now going to apply these skills to an ongoing problem facing our country: the invasion of cane toads.



Figure 1 Cane toads have taken over much of northern and eastern Australia.

Cane toads in Australia

In 1935, 101 cane toads were brought to Australia from Hawaii to eat an annoying pest – the cane beetle – which was destroying sugar cane crops and costing Australian sugar cane farmers a lot of money. The cane toads quickly multiplied and ate everything in sight: rubbish, plants and Australian native animals, including lizards, fish, frogs and birds. The toads ate just about everything except the cane beetle.

Cane toads have been successful in Australia for a number of reasons. They can live in a wide range of environments and can breed in almost any body of water, no matter how small. They produce very large numbers of eggs several times a season, and the adults live for a long time. Also, many of the diseases and parasites that keep cane toad populations under control in their native countries are not found in Australia.

Cane toads are a threat to native Australian animals. They eat a very wide range of native animals, including small vertebrates (such as birds) and invertebrates (such as skinks). Cane toads will also eat processed food, such as pet food. Because they are toxic to most animals that try to eat them, cane toads have very few predators.

We can learn much from the introduction of cane toads into Australia. Foxes, rabbits and carp (a type of fish) are three other types of animals that have been introduced into Australia and have since created problems.

When they arrived, cane toads ate everything in sight except for the cane beetle that they were brought here to eat. Cane beetles lived halfway up the cane plant where the toads couldn't reach, or in thick fields where the toads had no reason to go.



Figure 2 A cane beetle

Also, within five years, an insecticide – a chemical that kills insects – became available and the sugar cane farmers no longer needed to rely on the cane toad to destroy the cane beetle.

Australia is now home to more than 200 million cane toads. A group of people called the 'Kimberley Toad Busters' have joined together to get rid of cane toads and to stop them entering Western Australia. They have organised outings to capture and then humanely (kindly and without pain) kill the toads. When cane toads feel threatened, they release a poison from poison sacs behind their eyes. This poison can kill almost all animals, including the saltwater crocodile and humans.



Figure 3 In north-west Western Australia, a group called the Kimberley Toad Busters has formed to keep cane toads out of the area.

Check your learning 1.8

Recall and explain

1 **Recall** why cane toads are a problem in Australia.

2 **Recall** one solution used to fight the spread of cane toads in Australia.

Apply and analyse

3 Look back in time. **Identify** some simple questions that a scientist may have asked about cane toads before they were brought to Australia. Try and think of at least one question that starts with each of these words: 'why', 'what', 'where' and 'when'. Here's one to get you started: 'How quickly do cane toads breed?'

4 Draw some of the equipment that you would use on a toad-busting mission.

5 Write a list of toad-busting safety rules.

Evaluate and create

6 Use the questions you identified in question 3 to design a poster or information pamphlet warning people about the risks of introducing any type of foreign animal into Australia.

7 In a recent toad-busting mission, the largest toad caught was 14.5 centimetres long and the smallest was 7 centimetres. If the toads are such a pest, why do the toad busters bother measuring them?

8 Design an experiment that scientists could have conducted before the cane toad came to Australia. (Remember how quickly the cane toad breeds in the wild – your experiment must be controlled.)

- **a** What is the aim of your experiment?
- **b** What equipment would you need?
- **c** Write a list of questions you would ask yourself during the experiment.
- **d** Imagine that you have conducted the experiment. Using the information on this page, write the results of your experiment.
- **e** Write the conclusion. Remember to look back at the aim when you write this.

9 Use the conclusion of your experiment to write a letter to the Federal Environment Minister in 1934 (the year before the cane toad was introduced), requesting that the cane toad not be introduced. Make sure you back up your argument with at least three scientific facts.

1.9 Scientists communicate their findings

In this topic you will learn that:

- scientists share their findings with other scientists so that they can learn from one another
- scientists can communicate their findings in different formats, such as reports.

Communicating findings is an essential part of an experiment. Scientists might share their experiments and conclusions in a range of different formats, such as in posters and scientific journals or verbally. Across all of these formats, scientists include similar features and use similar language so that they can be understood by scientists worldwide. Scientists communicate with other scientists so that they can learn from one another and expand on each other's work.

results
measurement and observation taken in an experiment

discussion
a summary of findings, analysis of the design of an experiment; it includes any problems encountered and suggestions for improvement

conclusion
a statement that 'answers' the aim of an experiment; it should be clear and reasoned and relate very closely to the aim

Scientific reports

A scientific report is an essential part of an experiment – it is where results and findings are recorded. Scientists use a similar style and similar language in their reports so that they can be understood by scientists worldwide.

A report differs from an experimental logbook. A report is a written account of an experiment, whereas a logbook is where initial observations and notes are kept. Personal pronouns (such as 'I', 'we' and 'me') are not used in scientific reports.

A written report usually has eight parts:

1. title, date and partners (if you are working in a group) – don't forget to write your own name
2. **aim** or question – what you were trying to find out or why you were doing the experiment
3. **hypothesis** – your initial prediction about the outcome of the experiment (note: not all experiments contain a hypothesis)
4. equipment or materials – a detailed list of the equipment used
5. **method** – how you did the experiment, including diagrams of equipment; there are two reasons to write a method: the first is to plan what you are going to do (this method should be written using the present tense), and the second type is for a formal report (past tense should be used for this)
6. **results** – measurements and observations taken in an experiment, usually presented in a table, graph and/or diagram
7. **discussion** – your opportunity to discuss the findings, any problems that were encountered and suggestions for improvement or further investigation; this should be written in the third person
8. **conclusion** – the answer to the aim or question; it should be clear, reasoned and relate very closely to the starting aim or question and should be written in the third person.

aim
the purpose of an experiment

hypothesis
an initial prediction about the outcome of an experiment

method
a list of how to do an experiment

Writing scientific reports

Now it is your turn to do an experiment and produce your first scientific report. You will be working in pairs.

- Read through the instructions before you begin.
- Before doing the experiment, create an outline of the scientific report, including a table for your results.
- Conduct the experiment and fill in the table of results.
- Answer the discussion questions, practising using the third person.
- Check back to the aim to remind yourself of what your conclusion is answering. Copy the conclusion from the example and fill in the gaps.
- Evaluate the design of this experiment.

This sets out what you are trying to discover. It is the 'question' you are asking. This will be different for each experiment.

This is where any set questions are answered, and where you describe any unusual or interesting results. This is also where you can suggest improvements for an experiment.

1.9 Investigation: Egg bungy jump

INVESTIGATION

Aim

To drop an egg close to the ground safely.

A list of what you need

Materials

- Rubber bands (How many of them did you use?)
- Plastic or mesh bag
- Raw egg
- Wire or paper clip
- Retort stand
- Boss head
- Clamp
- Metre ruler

Method

How did you modify the original method?

Results

The distance an egg fell for each added rubber band. Draw a graph of the distance the egg fell against the number of rubber bands.

Number of rubber bands	Distance the egg fell
1	
2	
3	
4	
5	

The results often includes a table and a graph of your data.

The method gives step-by-step instructions and often a diagram of equipment.

Discussion

1. What difficulties did you have when measuring the distance the egg fell?
2. Would your results have been affected if the rubber bands were different sizes?
3. **Identify** one other variable that could have affected the results. Was this variable controlled? **Discuss**.
4. Extend your graph so that it shows how many rubber bands would be needed for a 2 metre drop. From this extrapolation/extension, how many rubber bands would you need to safely drop the egg as close to the floor as possible?
5. Would it have made any difference if you added extra weight to the egg before dropping it?
6. How could your results help people who want to bungy jump off a bridge?
7. What safety recommendations would you apply to anyone trying this experiment?

Conclusion

Summarise your findings, including the effect the independent variable had on the dependent variable.

This is an answer to the question you set out to investigate. Look back at the aim before writing the conclusion. Try to use one sentence and to write in the third person.

Figure 1 Investigation: Egg bungy jump

Check your learning 1.9

Recall and explain

1. **Identify** the two main parts of a scientific report.
2. **Recall** the eight steps for writing a scientific report.
3. **Explain** the purpose of a conclusion. Why is it written at the end of an experiment?
4. **Explain** why personal pronouns (such as 'I', 'we' and 'me') are not used in scientific reports.

Evaluate and create

5. **Discuss** why it is important that scientists complete scientific reports.
6. **Discuss** how a common format for all scientific reports would make it easier for scientists to communicate with one another.

1.10 Understanding key words helps to answer questions correctly

In this topic you will learn that:

- recognising key question words will help you to answer questions correctly.

Throughout Stages 4 and 5 Science, and all the way into HSC, you will notice a pattern to the way questions are written.

There's a list of key words that are used by teachers and textbooks to ask questions about what students have learnt. Questions will often ask you to 'explain', 'describe', 'compare' or 'evaluate'. But what do these words actually mean?

Understanding the differences between these words gives you a better chance of answering your homework or test questions correctly. The key words are outlined in Table 1.



Figure 1 What is the difference between examining and comparing something? It is important to understand the meaning of these key words.

Table 1 Key question words and their meanings

Key word	Definition
Account	Account for: state reasons for, report on; give an account of: narrate a series of events or transactions
Analyse	Identify components and the relationship between them; draw out and relate implications
Apply	Use, utilise, employ in a particular situation
Appreciate	Make a judgement about the value of
Assess	Make a judgement of value, quality, outcomes, results or size
Calculate	Ascertain/determine from given facts, figures or information
Clarify	Make clear or plain
Classify	Arrange or include in classes/categories
Compare	Show how things are similar or different
Construct	Make; build; put together items or arguments
Contrast	Show how things are different or opposite
Critically (analyse/evaluate)	Add a degree or level of accuracy, depth, knowledge and understanding, logic, questioning, reflection and quality to
Deduce	Draw a conclusion
Define	State meaning and identify essential qualities
Demonstrate	Show by example
Describe	Provide characteristics and features
Discuss	Identify issues and provide points for and/or against
Distinguish	Recognise or note/indicate as being distinct or different from; to note differences between
Evaluate	Make a judgement based on criteria; determine the value of
Examine	Inquire into
Explain	Relate cause and effect; make the relationships between things evident; provide why and/or how
Extract	Choose relevant and/or appropriate details
Extrapolate	Infer from what is known
Identify	Recognise and name
Interpret	Draw meaning from
Investigate	Plan, inquire into and draw conclusions about
Justify	Support an argument or conclusion
Outline	Sketch in general terms; indicate the main features of
Predict	Suggest what may happen based on available information
Propose	Put forward (for example, a point of view, idea, argument, suggestion) for consideration or action
Recall	Present remembered ideas, facts or experiences
Recommend	Provide reasons in favour
Recount	Retell a series of events
Summarise	Express, concisely, the relevant details
Synthesise	Put together various elements to make a whole

Check your learning 1.10

Recall and explain

1 **Appreciate** why it is useful to know the meaning of the key words outlined in Table 1.

2 **Define** the following words and write your own questions that use each.
   - **a** Evaluate
   - **b** Justify
   - **c** Deduce

3 **Contrast** the words 'compare' and 'contrast'.

REVIEW

Recall and explain

1 **Construct** a diagram of a:
   - **a** conical flask
   - **b** tripod stand
   - **c** test tube.

2 **Recall** the meaning of this safety sign.

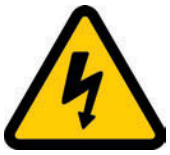


Figure 1 Identifying safety signs

3 **Describe** a fair test.

4 **Identify** the metric units for the following.
   - **a** Volume
   - **b** Temperature
   - **c** Time
   - **d** Mass

5 **Explain** mass.

6 **Explain** the purpose of controlling variables in an experiment.

7 **Classify** the following as quantitative or qualitative observations.
   - **a** The bus is red.
   - **b** The swimming pool smells of chlorine.
   - **c** I am older than 12 years old.
   - **d** The line to the tuckshop is 4 metres long.

8 **Explain** how a measurement is not very useful if you don't include the correct units.

9 Think about the Bunsen burner.
   - **a** Why is the Bunsen safety flame important?
   - **b** How do you get a safety flame with your Bunsen burner?
   - **c** The safety flame is not good for heating. Give two reasons for this.
   - **d** Which part of the blue flame is best for heating?



Figure 2 Bunsen burner

10 Which section of a scientific report would contain the measurements collected?

Apply and analyse

11 **Extrapolate** this graph to determine what would happen if the water was heated for 8 minutes.

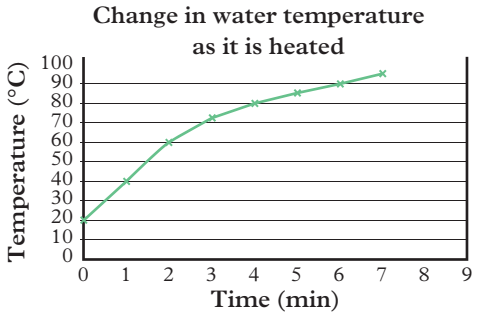


Figure 3 Temperature versus time graph

12 Make three observations and three inferences about:
   - **a** this textbook
   - **b** your own hand.

13 **Predict** what would happen if units were not the same everywhere in Australia.

14 **Construct** the correct graph for the following set of data on the number of deaths each year due to car accidents.

Year	Number of road deaths
2004	1583
2005	1627
2006	1602
2007	1603
2008	1437
2009	1488
2010	1352
2011	1291
2012	1310
2013	1193

15 **Interpret** the graph below to answer the following questions.

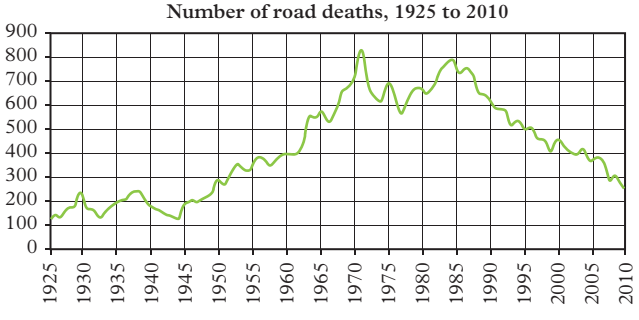


Figure 4 Number of road deaths, 1925 to 2010

   - **a** What label should be on the *x*-axis?
   - **b** What label should be on the *y*-axis?
   - **c** Which year was the number of road deaths at the highest level?

d How many road deaths were there in 1963?

e Describe the trend in:

i 1948–1966

ii 1972–1987

iii 1990–2010.

f What could have caused the trend from 1987 to the current day?

16 a Draw a graph from the data below that shows how much Enza has grown in her first 8 years.

Age (years)	Height (cm)
1	75
2	86
3	91
4	99
5	105
6	110
7	117
8	121

b Extrapolate the results to determine how tall Enza will be when she is 10 years old.

17 One of the first scientists to record their dissections was Leonardo da Vinci. Create a picture scrapbook of copies of some of Leonardo da Vinci's best work on the study of the human body.

18 How long is a palm? Check the length of your own palm against the suggested value in centimetres. How accurate do you think a measurement would be if you bought 50 palms of masking tape? What variation do you think you could get?

19 There are many unusual measurements. Can you find the answers to these measurement problems?

a How would you find the temperature inside a furnace?

b How can you measure the thickness of a sheet of paper?

c How fast do your fingernails grow? How could you measure this?

Evaluate and create

20 Design one of the following experiments:

- An experiment to test whether three types of materials are waterproof or not
- An experiment to see how high a rubber 'bouncy-ball' can bounce on different surfaces

Write an aim, hypothesis and method for the experiment. **Identify** the variables and make sure you control all but the experimental variable. Make note of any safety issues. Set it out like one of the experiments in this book.

21 Scientists present formally written reports in scientific journals. Many of these reports must be examined by other scientists before they will be accepted for printing. Suggest a reason for this.

Critical thinking

22 Astrology is called a 'pseudoscience' because it doesn't use a real scientific method to draw conclusions. Your teacher will provide you with a set of last week's horoscopes. They will be randomly numbered and the dates and star signs removed.

- Decide which horoscope from last week best fits you.
- Collate all the horoscope numbers and class members' names on the board.
- Your teacher will list the corresponding star signs for each number.

Once you have carried out the above tasks, answer these questions.

a How many horoscopes were correct?

b What does this tell you about astrology?

c Is astrology a science or a pseudoscience?

d Write down two new things you learnt from this activity.

Going further

23 Dissections and research involving animals have contributed significantly to our understanding of the human body. In fact, it would probably be fair to say that we couldn't have come this far without them. Critically **evaluate** the positives and negatives involved in using animals for medical research purposes. **Discuss** your points with a partner and share your thoughts with the class. Do you think animals should continue to be used for medical research?

24 Design an experiment to test the strength of different types of sticky tape. What is your independent variable? How will you measure your dependent variable? List all the variables that could affect the results. How will you control these? What materials will you need? Write out a method in a step-by-step manner.



Figure 5 Transparent sticky tape

Research

25 Choose one of the following topics for a research project. Your job is to plan the project rather than actually do the research. Planning is a very important tool. Place the topic in the centre of a mind map and fill the surrounding bubbles with big questions. Make sure your questions are big enough to give you broader insight into the topic, as well as broader issues. An example has been done for you below in Figure 6.

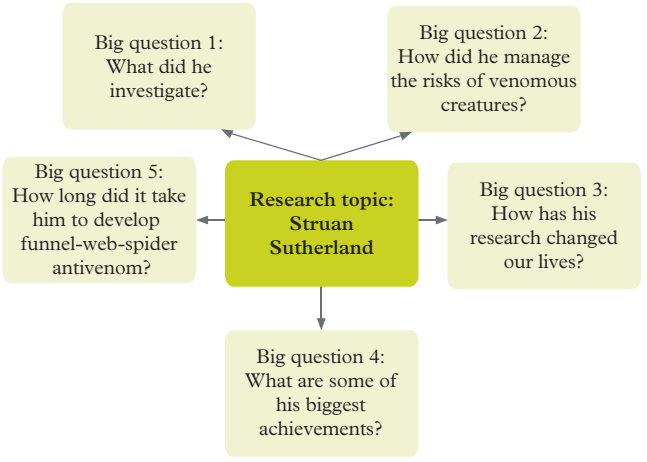


Figure 6 A mind map of research project planning

»Famous Australian scientists

What big questions do you want to explore about a notable Australian scientist? You could consider Frank Macfarlane Burnet, Douglas Mawson, Gustav Nossal, Mark Oliphant, Helen Caldicott, Nancy Millis, William McBride, Struan Sutherland or Suzanne Corey.

»Famous scientists in history

What big questions do you want to explore about a scientist who lived long ago? You could consider Archimedes of Syracuse, Hero of Alexandria, Galileo Galilei or Isaac Newton.

»Depending on variables

Variables are sometimes described as 'measured' instead of 'dependent', and 'experimental' instead of 'independent'. How are these terms similar? How are they different? When would each be used?

Reflect

By the end of Stage 4, you should be able to:

	I can do this.	I can't do this yet.	
Identify questions and problems that can be tested or researched and make predictions based on scientific knowledge.	☐	☐	Go to page 2–3.
Collaboratively and individually produce a plan to investigate questions and problems.	☐	☐	Go to page 4–5.
Follow a sequence of instructions to safely undertake a range of investigation types, collaboratively and individually.	☐	☐	Go to page 6–9.
Process and analyse data from a first-hand investigation and secondary sources to identify trends, patterns and relationships, and draw conclusions.	☐	☐	Go to page 10–13 and 16–19.
Select and use appropriate strategies, understanding and skills to produce creative and plausible solutions to identified problems.	☐	☐	Go to page 20–21.
Present science ideas, findings and information to a given audience using appropriate scientific language, text types and representations.	☐	☐	Go to page 22–23.

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FORCES

Why does an object's motion change?



Have you ever wondered ...

- Why do we not slip over when we walk on smooth surfaces?
- Why do our feet get hot if we drag them along carpet?
- Why do cars sometimes deform in car crashes?

2

SCIENCE UNDERSTANDING

In this chapter you will learn how to:

- identify changes that take place when particular forces are acting
- predict the effect of unbalanced forces acting in everyday situations
- describe some examples of technological developments that have contributed to finding solutions to reduce the impact of forces in everyday life, e.g. car safety equipment and footwear design
- analyse some everyday common situations where friction operates to oppose motion and produce heat
- investigate factors that influence the size and effect of frictional forces.

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Check your Student obook assess for these digital resources and more:

QuizletLive
Compete in teams to test your knowledge.

Assess quiz
Before you start this chapter, assess your science skills.

Check your Teacher obook assess for these resources and more:

QuizletLive
Launch a quiz for your students on key concepts in this chapter.

2.1 A force is a push or a pull

In this topic you will learn that:

- unbalanced forces act on everything, causing objects to move or stop moving, or change speed, shape or direction
- the unit used to measure a force is a newton (N).

force
a push or pull that, if unbalanced, can cause a change in an object's motion

calibrate
to check the accuracy of a meter against known measurements

newton
the unit used to measure force; symbol N

A **force** is a push or pull that happens when two objects interact. Sometimes forces are easy to identify and describe, such as a foot kicking a ball. Other forces are harder to identify and describe; for example, the force that keeps you on the ground.

Forces in action

Forces act on everything around us. Usually, more than one force is acting on any object at one time, but often we do not notice them. You have many forces acting on you at the moment. For example, when you sit on a chair, gravity is pushing you down. The chair is pushing back against you. Because these forces acting on you are in balance (the same strength but opposite directions), you do not move.

Video
Forces in tennis

When you kick or throw a ball, you need to push the ball. This push force causes the ball to move. When you catch a ball, you are still giving it a push. This time, the push force causes the ball to stop moving.

Forces act on everything around us all the time. They cause objects to:

- begin to move
- speed up
- slow down or stop moving
- change direction
- change shape
- remain still.

Examples of these forces are shown in Figures 2–7.

Measuring forces

spring balance
a device consisting of a spring and a scale, used to measure forces in the laboratory

One way to 'see' a force at work is to measure it. Push forces can be measured with a set of scales like the ones you might find in a kitchen or bathroom. Pull forces can be measured using a **spring balance**. As shown in Figure 1, a stiff spring in the balance stretches when an object pulls on it. The distance the spring stretches represents the amount of force applied. This distance is measured by a marker on the spring balance. A rubber band can measure the size of forces in a similar way to a spring balance. Before we can use a rubber band to measure a force, it must be **calibrated**. This means we need to match the stretch of the rubber band to the force pulling on it.

The unit used to measure forces is called a **newton** after English physicist Isaac Newton (1642–1727), who first described the force used to pull an apple from a tree. Spring balances are also known as newton meters. Scientists around the world have agreed to this standard measurement so that they can communicate with one another. In every country, the force of 100 grams being pulled to the centre of the Earth is about 1 newton (N). This is about the same as one large chocolate bar sitting on your hand.

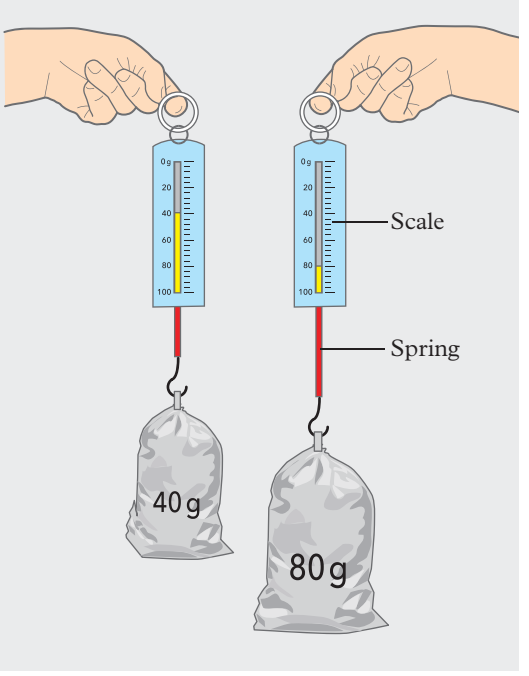


Figure 1 Spring balances are used to measure force.

SKILLS LAB **2.1:** Measuring forces
Go to page **353**.



Figure 2 Begin to move. The golf club pushes the ball. The club exerts a force on the ball, causing it to begin to move. If the club misses the ball, there is no additional force on the ball from the club and the ball stays still.



Figure 3 Speed up. When the skateboarder wants to move faster, they use their foot to exert a force on the ground.



Figure 4 Slow down. The brakes on this bicycle wheel push down on the tyre, causing the tyre to slow down. This in turn brings the bicycle to a stop.



Figure 5 Change direction. The tennis racquet pushes the ball in a different direction.



Figure 6 Change shape. The fingers push the plasticine into a different shape. When the fingers stop pushing, the plasticine no longer changes.



Figure 7 Remain still. The forces acting on this ball stop it from moving.

Check your learning 2.1

Recall and explain

1 **Define** the term 'force'.
2 **Recall** six things that forces do.
3 **Recall** the unit used to measure force.

Apply and analyse

4 Order these forces from biggest to smallest.
   a A truck hitting a pole
   b A rocket being launched
   c Typing one letter on a computer keyboard
   d Kicking a soccer ball

5 **Compare** the spring balances used for weighing a bag of flour with those used for weighing a spoon of baking powder.

Evaluate and communicate

6 Can you see a force? Always, never or sometimes? **Justify** your answer in the format of your choice, such as paragraph, poster or speech.

Skills builder: Planning investigations

7 A student was using the force measurer from Skills Lab 2.1 (see page 353) when the rubber band broke.
   a **Identify** the aim of Skills Lab 2.1. (THINK: Why was the student using the force measurer?)
   b Suggest why the original force measurer might have broken. (THINK: What needs to change to make it work?)
   c **Propose** a new way to conduct Skills Lab 2.1. (THINK: Could a different rubber band be used with the same scale?)

2.2 An unbalanced force causes change

*

In this topic you will learn that:

- when forces acting on an object are balanced, the object's motion does not change
- forces acting on an object are unbalanced when there is a change to the speed, direction of motion, or shape of an object.



Figure 1 Forces can balance each other.

Forces always come in pairs. Forces are balanced when they are pushing or pulling equally in opposite directions. If one of the push or pull forces is larger than the other, the object will change its speed, direction of motion or shape. When this happens, the forces are said to be unbalanced.

Balanced forces

Pushing on a brick wall does not usually cause the brick wall to move. This does not mean your force did not exist. There are many forces around us, but most of them do not cause any change in motion. This is because the forces are balanced. It means they are equal in size but opposite in direction. If the forces of the two people in Figure 1 balance each other, the people stay still. This is because they are pushing or pulling with equal and opposite forces.

balanced forces
two forces equal in size and opposite in direction

Balanced forces are very important. Two tug-of-war teams will be balanced if they pull with the same amount of force but in opposite directions.

Unbalanced forces

unbalanced forces
two or more forces that are unequal in size and direction and therefore change an object's speed, direction or shape

Unbalanced forces are also very important. Consider the forces acting on the barbell in Figure 2. The barbell stays in the air at a particular height because the forces on it are in balance. The weightlifter is pushing the barbell up with exactly the same amount of force as the Earth is pulling down. To move the barbell up, the weightlifter must use a stronger force than the Earth's pull. This will make the forces on the barbell unbalanced.

Evidence of an unbalanced force

There are three ways you can tell if a force is unbalanced. Forces are unbalanced if there is a change in an object's:

- speed
- direction
- shape.



Figure 2 A weightlifter applies a force to lift the barbell.

CHALLENGE
2.2: Design a ball whacker
Go to page **354**.

If a ball is resting on the ground, then all the forces acting on it are balanced. If two people are pushing equally on a stationary object in opposite directions, then the forces are balanced and the object does not move. If one person starts pushing harder, then the object will start to move. There is a change in motion because the forces are unbalanced.

Consider a soccer ball rolling towards the goal. If the goalkeeper kicks it away, then the ball will change direction because the goalkeeper's kick unbalanced the forces.

Playdough sitting on the bench will not change unless you add a push force with your finger. The evidence for this unbalanced force is a change in shape.



Figure 3 This door is opened by applying either a direct push or pull force (contact).

Contact forces

Contact forces involve two objects touching each other. Some forces make objects move because of a direct push or pull. It is much easier to move a pencil if you push it with your finger. Your finger has to touch the pencil or be in contact before the pencil will move. This is called a contact force. Friction is also an example of a contact force, which you will learn more about later in this chapter.

If an object is able to push or pull another without touching, it is called a **non-contact force**. Magnetism and **gravity** are examples of non-contact forces.

contact force
a force that occurs when two objects are touching each other

non-contact force
a force that operates between two objects when they are not touching each other, e.g. gravitational force

gravity
a force of attraction that objects have on one another due to their masses

Check your learning 2.2

Recall and explain

1 **Identify** an example of balanced forces acting on an object.

2 **Describe** how the forces acting on the objects in the following situations are unbalanced.
- **a** Pushing down the lever on the toaster
- **b** Jumping on a trampoline
- **c** A car starting to move

Apply and analyse

3 **Examine** Figure 2. What are the forces acting on the barbell?

4 **Explain** why weightlifters get tired when they hold heavy masses in the air.

5 **Explain** why a brick wall does not fall over when you push it. Why can a bulldozer push it over?

6 Jack pushes a trolley quickly down a supermarket aisle. He builds up speed and then stops, letting go of the trolley.
- **a** **Predict** what would happen to the trolley.
- **b** **Explain** your answer in terms of the forces acting on the trolley.

Skills builder: Questioning and predicting

7 Sam wants to investigate if having more people on one side of a tug-of-war will affect the result of the game. He has created this scientific question for his investigation: 'Is it good to have lots of people for tug-of-war?'
- **a** **Identify** what is wrong with Sam's question. (THINK: Is this question specific enough and easy to test?)
- **b** **Propose** your own scientific question for Sam's investigation. (THINK: How does your question improve on Sam's question?)

2.3 Forces can be added together

In this topic you will learn that:

- forces can be added together to calculate the net force working on an object
- force diagrams use arrows to represent the direction and strength of a force.

If you tried to lift a heavy object such as a piano, you would not succeed because the upward force you exerted on the piano would be too weak. But if a few of your friends helped you by adding their force to yours, the combined upward forces would be stronger than the downward pull of the Earth. The **net force** is the combination of all the forces acting on the piano. If the piano is lifted up, the forces are unbalanced and the net force on the piano is upward.

If an object is stationary (not moving) or moving at a steady speed in the same direction, then the net force acting on that object is zero. All the forces are balanced. If an object changes its speed (by speeding up or slowing down), shape or direction, then a net force must be acting on it.

In tug-of-war (see Figure 1), if one team pulls with more force, the rope will move towards them. If the rope stays in the same place while both teams pull, the net force acting on the rope must be zero.

net force
a combination of all the forces acting on an object

normal force
the force of a surface pushing back on another when contact is made

Drawing force diagrams

Force diagrams show all the forces acting on an object. There is one arrow to represent each force. The arrows on a force diagram can tell you information about the forces being exerted:

- The length of the arrow shows the size of the force. For example, a short arrow shows a weak force and a long arrow shows a strong force.
- The direction of the arrow shows the direction of the force.

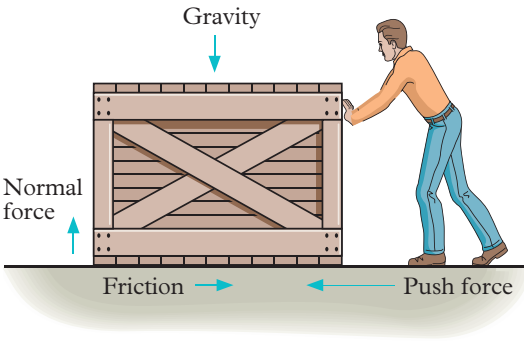
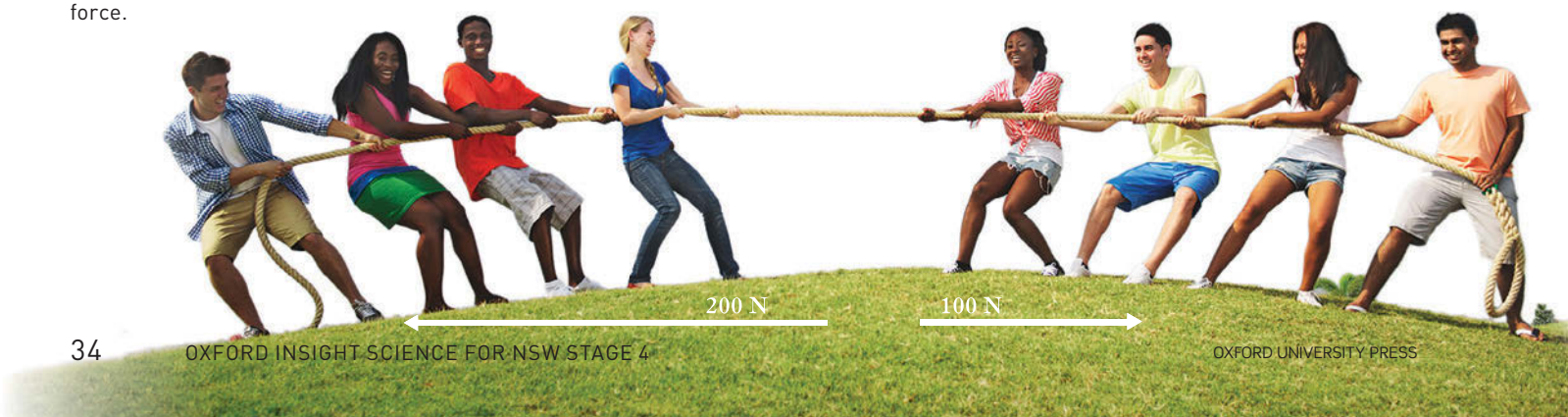


Figure 2 The arrows in this diagram show the forces acting on the box as it is moved.

Figure 1 shows a tug-of-war between two teams. The arrows show the pull force they are exerting on the rope. The arrow for the 200 N force is twice as long as the arrow for the 100 N force, but they are showing opposite directions. Which team will win? Force diagrams can also show normal force, which is the force of a surface pushing back on another when contact is made. For example, the box in Figure 2 doesn't sink into the floor. Even though gravity is pushing down on the box, the **normal force** acts in the opposite direction.

Figure 1 When forces are unbalanced, a change in motion will occur, with the greatest force 'winning'. In a game of tug-of-war, if one team pulls with a force of 100 N to the right and the other team pulls with a force of 200 N to the left, the net force is 100 N to the left. The team on the left will win the game because both teams will move that way. Unbalanced forces lead to a movement in the direction of the greater force.



Worked example: Drawing force diagrams

Question

Construct a force diagram to represent the car being pushed in Figure 3.



Figure 3 When one of these people tries to push the car, they are not strong enough. But their combined net force is enough to move the car.

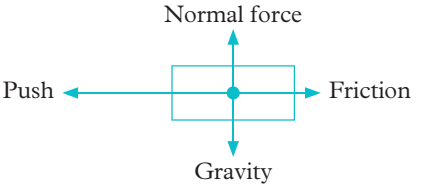
Solution

Step 1 Draw a box or dot to represent the car.

Step 2 Identify all the forces acting on the car, and in which direction they are acting. In this example, the forces are the people pushing on the car, the friction acting in the opposite direction to the movement, gravity acting down on the car and the force of the ground pushing upward (called normal force).

Step 3 Draw an arrow for each of these forces. Use a ruler to draw straight lines. The push causes the car to move, so it must be an unbalanced force. Therefore, the arrow for the push force should be longer.

Step 4 Label the arrows.



Check your learning 2.3

Recall and explain

1 **Define** the term 'net force'.

2 **Identify** two examples where forces cancel each other out and where two forces add together.

3 **Explain** what the arrows represent on a force diagram.

Apply and analyse

4 If Sally can push with 150 N and Marilla with 200 N in the same direction, **calculate** the force they push with together. **Calculate** the net force if they push in opposite directions.

5 **Construct** a diagram of two people having a tug-of-war. Give them names and draw arrows to show the force they are exerting on the rope. Identify the winner.

6 **Construct** a force diagram for the following examples.

- **a** A broken-down car being pushed
- **b** A ball being thrown
- **c** Laying still on the grass

Evaluate and create

7 **Identify** if the forces acting on a car are balanced or unbalanced in each step. **Justify** each of your answers.

- **a** A car is stationary.
- **b** It then starts moving and keeps travelling at a constant speed on a straight road for 5 minutes.
- **c** It next turns right.
- **d** Then it continues to travel straight on the road.
- **e** The driver sees a dog crossing the road, so he brakes and the car stops after 1 minute.

Skills builder: Communicating

8 Your classmate does not understand why his team lost a tug-of-war, even though he had more people on his side.

- **a** **Construct** a force diagram to demonstrate the forces in the tug-of-war. (THINK: What kind of representation is normally used to demonstrate forces?)
- **b** Label your force diagram. (THINK: What does your classmate need to know about heat?)

2.4 Friction slows down moving objects

In this topic you will learn that:

- friction resists motion between objects
- friction produces heat.



Figure 2 The friction from rubbing two sticks quickly together can produce enough heat to start a fire.

What is friction?

friction
the force that acts to oppose the motion between two surfaces as they move over each other

Friction is the force that resists movement between two objects in contact. In other words, friction slows down moving objects. Friction happens as surfaces rub together or try to slide across each other. For example, it is much easier to slide along ice than along a gravel road. This is because the friction of the gravel road slows the forward motion.

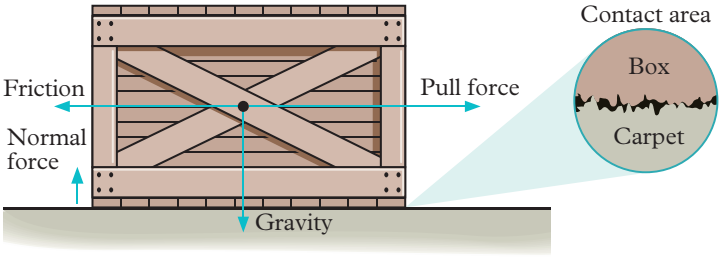


Figure 1 Friction between the box and the carpet on the ground makes it harder to slide the box around.

Friction acts in the opposite direction to movement. The greater the friction, the more the movement slows down and eventually stops. Any time a movement is slowed down, it is because of friction.

Imagine that you need to move a heavy wooden box across a carpeted room (see Figure 1). It would require more force to slide the box along carpet than a smoother surface such as floorboards. This is because the carpet generates more friction.

Resource
STEM activity:
What a drag!

Friction produces heat

When you rub your hands together quickly, you can make your hands feel warmer. The friction between them produces heat. All friction forces produce heat as the surfaces of objects rub together.

Think about the way some people can start a fire just by rubbing two sticks together or striking a match. The friction from such movement can create enough heat to produce a flame.

Aboriginal and Torres Strait Islander peoples developed different methods for creating fire with friction. One method, sometimes called the fire drill, involves a flat piece of a wood and a long stick. The long 'drill' stick is held upright with one end placed on the flat piece of wood. The drill stick is then twirled quickly, causing friction. The saw dust that collects in this process can ignite to become fire.

How to decrease friction

The size of friction depends on how easily two surfaces rub over each other. Smooth surfaces move more easily over each other than coarse surfaces. Therefore, the friction between smooth surfaces is smaller than the friction between coarse surfaces. To reduce friction, we need to find ways to make movement between surfaces easier.

Rollers or balls are one way to reduce friction. Because the balls roll across the ground, it is much easier than if they were dragged along. Tiny balls are often used as bearings to allow two surfaces to slide over one another easily.

INVESTIGATION
2.4: What if the amount of friction was changed?
Go to page **354**.

Hovercrafts and air pucks have low friction because they use a layer of air to glide over a surface. There is no contact between the surfaces and almost no friction as a result.

Lubricants, such as oils and grease, also reduce friction. This is called **lubrication**. If a kitchen drawer sticks, you can use candle wax or soap to lubricate it. Lubricants work by coating the surface with an oily or waxy substance, which makes them slippery. Putting oil on bicycle chains and grease on the wheel axles makes the wheels spin more easily and with less friction.

Air resistance, or drag, is the friction between a moving object and the air it is moving through. Air resistance limits the speed of an object in the air. Air resistance is necessary for parachutes, but it is a problem for cars and trucks. **Streamlining** (making the surface smooth and rounded) helps overcome air resistance.

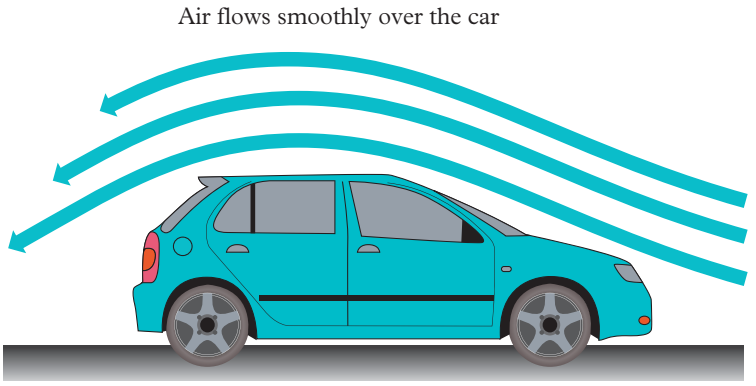


Figure 3 Streamlining reduces friction.

Footwear for friction

Friction can help motion. When buying sports shoes, many people look for shoes with good grip. This grip prevents the shoes from sliding when they run and stop. The grip provides friction between the ground and the wearer. When you start walking, you rely on the shoe rubbing against the ground so that you can push forward. When you try to stop, you rely on the friction between the shoe and the ground to stop your movement. Without friction, your feet would just slip over the ground. It would be like trying to walk on ice.

Footwear has also developed to reduce the impact of your feet hitting the ground.



Figure 4 Friction between the shoe and the ground stops a person from sliding around.

lubrication
using a lubricant, such as oil or grease, to decrease friction

air resistance
the friction between a moving object and the air it is moving through

streamlining
making a surface smooth and rounded to reduce friction

Check your learning 2.4

Recall and explain

1 **Recall** three examples where friction is useful, and three examples where friction is a problem.
2 **Explain** how speed and friction are related.
3 **Identify** two examples of friction slowing down an object.

Analyse and apply

4 Using the examples of friction you identified in question 3, **analyse** how these examples slow down an object and how they produce heat.
5 Why does the tread on the tyres of your bike wear down over time? **Explain** this in terms of force.
6 In a world without friction, **predict** what would happen if you tried to:
   a go down a slide in a playground
   b play tenpin bowling
   c tie your shoelaces
   d ride a bike up a hill.

Skills builder: Processing and analysing

7 Vivienne used the same pushing force on her textbook to slide it across different surfaces. She recorded her results in the table below.

Surface	Distance the textbook travelled (m)
Floorboards	1.2
Carpet	0.9
Linoleum	1.6

   a **Identify** what kind of graph you would use to represent this information. (THINK: Would you use a bar chart or a line graph?)
   b **Construct** a graph for this data using your answers from part a. (THINK: What other features should a graph have? Remember to label your *x*- and *y*-axes and include a title.)

2.5 Seatbelts and safety helmets save lives

In this topic you will learn that:

- technological developments, such as seatbelts and helmets, reduce the impact of forces in everyday life.

When objects are stationary or moving at a constant speed, the forces are balanced. When the forces are unbalanced, they can cause a change in speed, shape or direction. When cars or bicycles stop suddenly, passengers or riders can experience unbalanced forces. Australian government regulations mandate the wearing of seat belts or safety helmets to prevent these unbalanced forces causing damage to passengers.

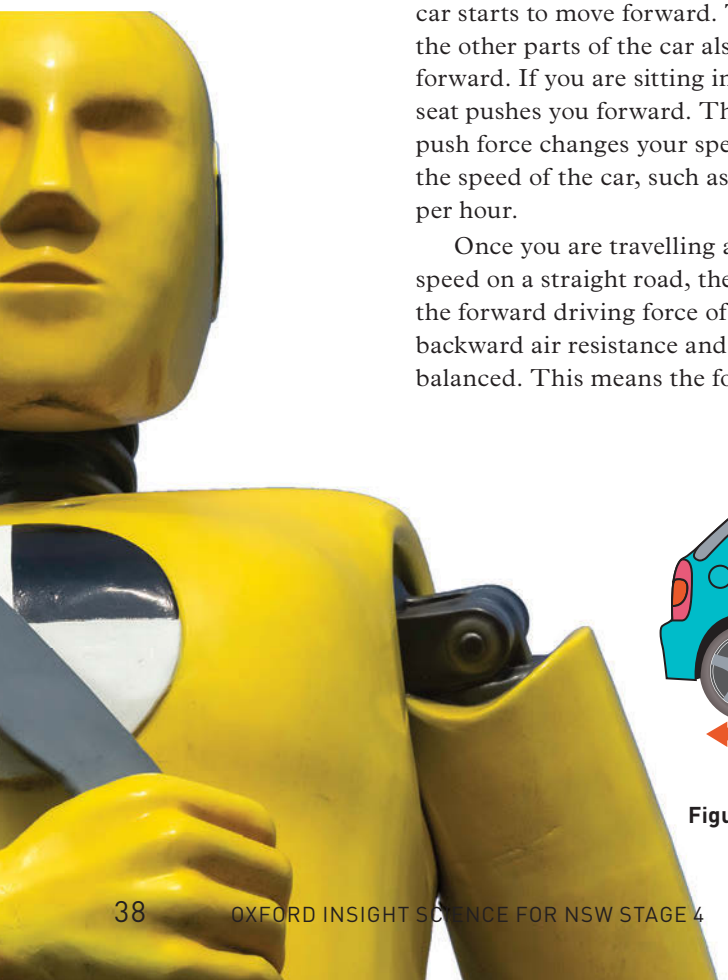
Seatbelts and car safety

When a car starts to move, the engine provides a driving push force on the wheels. The friction between the road and the wheel stops the wheel from spinning freely, and the car starts to move forward. This means all the other parts of the car also start to move forward. If you are sitting in a car, then the seat pushes you forward. This unbalanced push force changes your speed from zero to the speed of the car, such as 100 kilometres per hour.

Once you are travelling at a constant speed on a straight road, the forces between the forward driving force of the car and the backward air resistance and friction forces are balanced. This means the forces between you and the car are also balanced. Balanced forces mean there is no change in speed, shape or direction. Often, when you are in a moving car, you might not notice that you are moving at 100 kilometres per hour. If you stop to think about it, you might realise that 100 kilometres per hour is the same as running a 100 metre race in 3.6 seconds. Yet you do not notice the forces involved because they are balanced.

You do notice the forces when the car stops suddenly. Most cars stop when the engine stops its driving force and the brakes prevent the wheels from moving. Because the car is still moving forward, there is friction between the wheels and the road. This means there is more force stopping the car than there is pushing it forward. The unbalanced forces change the car's speed from 100 kilometres per hour to zero. But what stops you?

As a passenger, your speed will only change if there is an unbalanced force exerted on you. The friction between the wheels and road stop the car; however, it does not stop you. You need a force to stop you moving forward. Fortunately, the laws in Australia encourage everyone to wear a seatbelt.



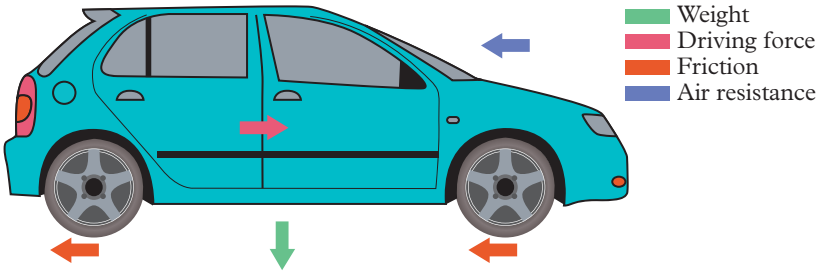


Figure 1 There are many forces acting on a moving car.

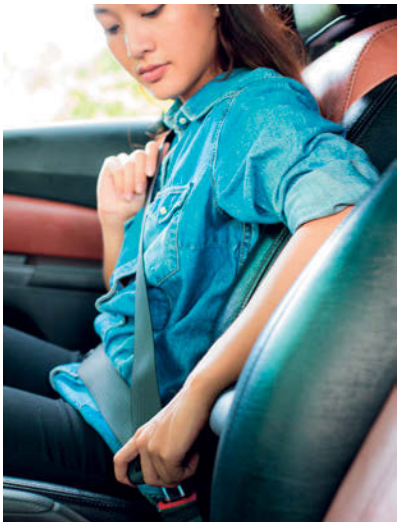


Figure 2 Seatbelts hold us in place when a car stops suddenly.

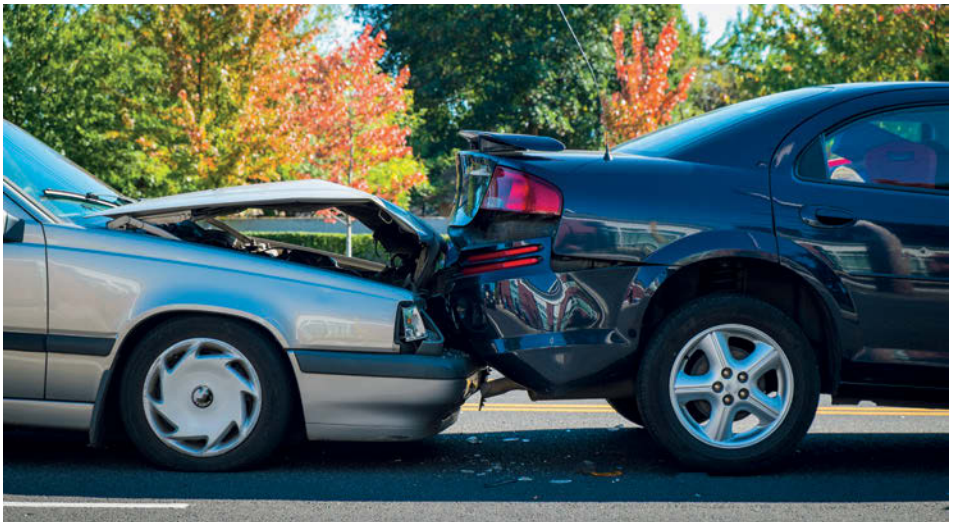


Figure 3 The unbalanced forces in a car crash can cause a change in speed and shape.

When the car stops, the seatbelts attached to the car also stop. These seatbelts then provide an unbalanced force to change your speed from 100 kilometres per hour to zero.

Just imagine what would happen if you were not wearing a seatbelt? The car would stop, and you would keep going at 100 kilometres per hour until a force slowed you down. This could be the seat in front of you, the windscreen or the road in front of the car. This type of unbalanced force would change not only your speed but also your direction and shape.

Safety helmets

Safety helmets are an essential item when riding a bike, and the wearing of them is strictly regulated by Australian law. Just like a passenger in a car, a cyclist can experience unbalanced forces when stopping suddenly. In an accident, such as hitting a car door, the unbalanced force stops the bike; however, the cyclist keeps moving forward until their forces become unbalanced. The unbalanced force results in a change in the rider's shape and speed. As bicycles do not have seatbelts, the movement of the cyclist is often unstopped when they hit the road. A helmet can help prevent direct contact between the cyclist's head and the road while spreading the force over a greater surface area. For this reason, Australian regulations require all cyclists to wear an appropriate safety helmet.

Check your learning 2.5

Recall and explain

1 **Identify** the forces on a car travelling at a constant speed of 100 kilometres per hour on a straight road.

2 **Explain** why you do not notice how fast you are travelling when you are a passenger in a car travelling at 100 kilometres per hour on a straight road.

Evaluate and create

3 **Identify** and **describe** how one technological development is reducing the impact of forces for car safety.

4 **Investigate** the rules in New South Wales around bike safety to reduce the impact of forces. Present your findings as an A4 poster.

Skills builder: Problem solving

5 **Investigate** Australian government regulations about wearing seatbelts when in a moving car.

- a **Identify** the problem that seatbelts are trying to solve. (THINK: Why do we need to wear seatbelts?)
- b **Evaluate** the rules around wearing seatbelts when in a moving car. (THINK: Do you think these rules work? Are these rules enough?)



Figure 4 A safety helmet spreads the force of an impact to the head across a great surface area.

REVIEW

Multiple choice

1 **Identify** which of the following is an example of a pull force.
- **A** Kicking a soccer ball
- **B** Diving into a swimming pool
- **C** Dragging a box toward you
- **D** Pushing a shopping trolley

2 **Identify** how you would describe the net force of a barbell being lifted.
- **A** Upward net force
- **B** Downward net force
- **C** Zero net force
- **D** Sideways net force

3 **Identify** the forces.
- **A** A ball flying through the air after it was thrown
- **B** A book sitting on a table, not moving
- **C** A piece of modelling clay being moulded into a different shape
- **D** A car slowing down for a stop sign

Recall and explain

4 **Identify** two examples of a push force.

5 **Identify** two examples of a pull force.

6 Think back to the start of your day. **Describe** the forces that you experienced from the time you got up to the time you arrived at school.

7 **Explain** which of the following involve forces, and which of the following do not.
- **a** Opening a window
- **b** Turning a screw with a screwdriver
- **c** Smelling food cooking
- **d** Modelling clay
- **e** Standing on a diving board
- **f** Watching a candle burn

8 **Explain** the difference between a contact force and a non-contact force.

9 **Outline** the effects of balanced and unbalanced forces on an object.

10 **Outline** three ways to reduce friction.

11 **Describe** how one technological development has reduced the impact of forces to make cars safer.

Apply and analyse

12 **Examine** Figure 1.
- **a** **Describe** the net forces acting on the ball.
- **b** **Predict** what will happen to the ball.
- **c** Draw a force diagram of forces acting on the ball to support your prediction.



Figure 1 The force of Benji Marshall kicking the ball is easy to identify and describe.

13 **Analyse** the following in terms of friction.
- **a** Gymnasts putting chalk on their hands
- **b** People driving cars on ice or snow putting chains on their tyres
- **c** A car using more petrol when it has a load on the roof
- **d** A person having difficulty running across ice

14 **Calculate** the size and direction of net force in the diagrams below.

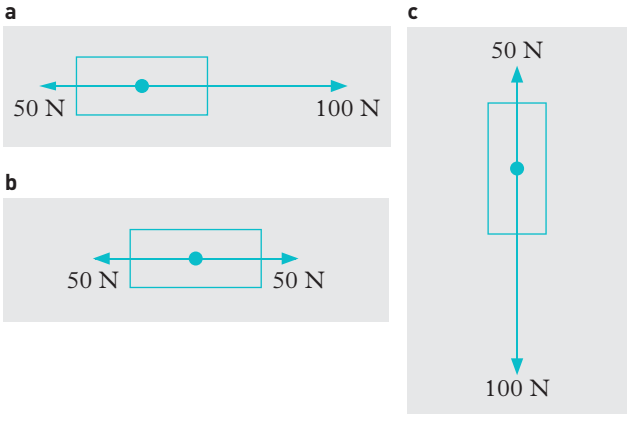


Figure 2 Net force diagrams

15 Two students worked together to investigate the effect of the mass of objects on the size of the friction force. They pulled different weights with the same size force on the same surface. Their results are in the table below.

Mass (kg)	Friction Force (N)
0.25	0.63
0.50	1.30
1.00	2.50
2.00	5.00
3.00	7.50

a **Identify** the independent and dependent variables.

b **Identify** one controlled variable.

c **Construct** an appropriate graph using the data in the table.

16 You are camping in a remote area, but you have left your matches at home. **Explain** how you can start a fire for cooking.

17 Use your understanding of forces to **account** for a row of dominos falling over.



Figure 3 Forces acting on the dominos when one domino in the chain is pushed

Evaluate and create

18 **Determine** which of the following cars would be better as a racing car. **Account** for your answer.



Figure 4 Which of these cars are better for racing?

19 Think about how far a toy car and a marble would roll along a flat bench.

a **Predict** which would have the least friction. **Justify** your response.

b **Predict** which would roll the furthest. **Justify** your response.

c **Explain** the connection between rolling and friction.

20 **Discuss** why surfers often wax their surfboards.

21 If you used the same pushing force in each of the following cases, **determine** which surface an object would move over the fastest: sand, wood, or metal coated in oil. **Justify** your answer.

22 **Propose** three things that are more difficult, and three things that are easier, to do without friction. **Account** for your answer.

Critical thinking

23 Matilda fills her car with petrol and drives 100 kilometres along a freeway. She then turns off the freeway and travels 100 kilometres along country roads, one of which is very rough.

a **Identify** in which part of the trip the car would use more petrol.

b **Justify** your answer using your knowledge of forces and friction.

24 Harry is pushing a full shopping trolley up a steep hill. He pushes the trolley with all of his strength, but it goes nowhere.

a **Explain** what is happening to the trolley in terms of forces.

b **Construct** a force diagram to represent the forces acting on the trolley.

c Suggest a solution that might help Harry to get the trolley and all of its groceries to the top of the hill.

Going further

25 Imagine that you want to move a big box across a room. Your friend comes to help you and he pushes down on the box.

a **Identify** if your friend would make your work easier or more difficult.

b **Justify** your answer.

26 Think about a car travelling at a constant speed around a roundabout. **Explain** if the forces acting on the car are balanced or unbalanced.

Research

27 Choose one of the following topics to research further. Present your findings in a format that best fits both the information you have found and the understandings you have formed.

»Seatbelts

The wearing of seatbelts in cars became compulsory in Australia in 1970. Research the materials that are used to make seatbelts. Use your knowledge of forces to explain how seatbelts prevent injury in a car accident.

»Aeroplanes

There are forces always acting on objects. What are the push and pull forces acting on an aeroplane? How do these push and pull forces change as an aeroplane takes off, flies and lands? Research the forces acting on an aeroplane and draw a labelled diagram to show the forces.



Figure 5 What forces act on an aeroplane?

»Footwear for friction

Investigate how different types of footwear have been designed to reduce friction. What type of footwear do you think is the best for reducing or increasing friction? What features have designers included to manage friction? Draw a diagram of one shoe and label how it has been designed to improve the impact of friction.



Figure 6 Shoes are manufactured with many different soles, depending on the function of the shoe.

Reflect

Now that you have completed this chapter, reflect on your ability to do the following:

	I can do this.	I can't do this yet.	
Identify changes that take place when particular forces are acting.	☐	☐	Go to page 30–31.
Predict the effect of unbalanced forces acting in everyday situations.	☐	☐	Go to page 32–33.
Describe some examples of technological developments that have contributed to finding solutions to reduce the impact of forces in everyday life, e.g. car safety equipment and footwear design.	☐	☐	Go to page 36–39.
Analyse some everyday common situations where friction operates to oppose motion and produce heat.	☐	☐	Go to page 36–37.
Investigate factors that influence the size and effect of frictional forces.	☐	☐	Go to page 36–37.

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FIELDS

How can objects move if nothing is touching them?

Have you ever wondered ...

- Why do people float in space, but not on Earth?
- How does a compass know which way is north?
- Why does clean, dry hair stand up when you brush it?

3

SCIENCE UNDERSTANDING

In this chapter you will learn how to:

- use the term 'field' in describing forces acting at a distance
- identify ways in which objects acquire electrostatic charge
- describe the behaviour of charged objects when they are brought close to each other
- investigate everyday situations where the effects of electrostatic forces can be observed, e.g. lightning strikes during severe weather and dust storms
- identify that the Earth's gravity pulls objects towards the centre of the Earth
- describe everyday situations where gravity acts as an unbalanced force
- distinguish between the terms 'mass' and 'weight'
- describe the behaviour of magnetic poles when they are brought close together
- investigate how magnets and electromagnets are used in some everyday devices or technologies used in everyday life.

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Check your Student obook assess for these digital resources and more:

QuizletLive
Compete in teams to test your knowledge.

Assess quiz
Before you start this chapter, assess your science skills.

Check your Teacher obook assess for these digital resources and more:

QuizletLive
Launch a quiz for your students on key concepts in this chapter.

3.1 Magnets push and pull

In this topic you will learn that:

- magnets exert non-contact forces that act in a magnetic field
- like magnetic poles repel and unlike magnetic poles attract each other.

Magnetic forces are non-contact forces. This means they do not need to physically make contact with an object to act on it. Instead, non-contact forces act in a **field**.

field
the area in which a non-contact force can act on an object

How magnets push and pull

Magnets are made of an alloy (a mixture of metals) that is mostly iron. The bar magnets used most commonly in schools are usually made of the alloy alnico, which is iron mixed with aluminium, nickel and cobalt. New, strong magnets are made from metals known as rare earth metals. These are much stronger than normal magnets and do not lose their magnetism.

One end of a magnet is labelled 'N' for north and the other end 'S' for south. If you hang a bar magnet by a piece of string, the north end will swing to point north. The magnet is said to have two **magnetic poles** – north and south.

magnetic poles
north and south ends of a magnet

When the north pole of one magnet is placed near the south pole of another magnet, the two are pulled to each other. The two **unlike poles** (a north and a south) attract each other. Magicians use this **attraction force** to slide something along a table. You can do this too. Place one magnet on top of a thin table and a second magnet under the table. Can you make the top magnet move? Can you see the pull force? Are the two magnets contacting each other?

unlike poles
opposite poles of magnets

attraction force
the force that attracts one object to another

When two **like poles** (two north poles or two south poles) are placed together, they push each other apart. You can use one magnet to push another magnet along a table. This is called a **repulsion force**.

like poles
two north poles or two south poles of a magnet

repulsion force
a force that pushes one object away from another

Mapping magnetic fields

The area around a magnet, where its force can push or pull other magnetic materials, is considered part of its **magnetic field**. The further away an object moves from the magnet, the weaker the field is.

magnetic field
a three-dimensional space around an object where a magnetic force is experienced

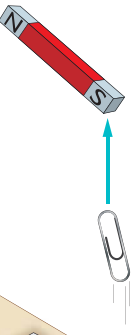


Figure 1 The attraction between paperclips and the magnet is a non-contact force.

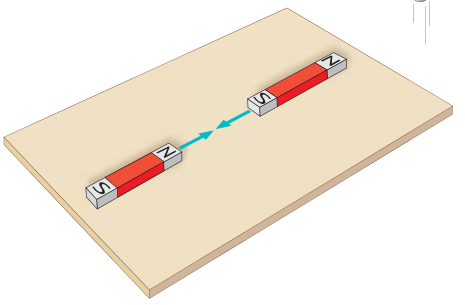


Figure 2 The north pole of one magnet is pulled by the south pole of another magnet.

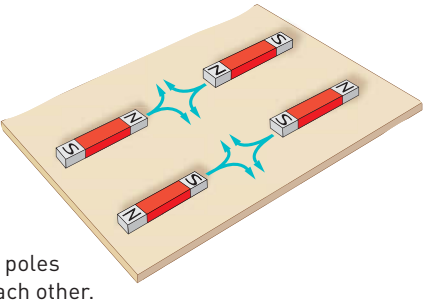


Figure 3 Like poles push/repel each other.

Although we cannot see a magnetic field, we can use objects such as iron filings to observe how magnetic fields behave (see Figure 4). The iron filings act like magnets and line up along the magnetic field. You can draw this pattern to make a map of the magnetic field. Magnetic field lines are used to represent fields. These lines always start at north poles of magnets and end at south poles. Closer lines mean a stronger magnetic field (see Figure 5). The lines never cross each other. The arrows on each magnetic field line represent the direction of the magnetic field at any point.

CHALLENGE
3.1: Can you use the push and pull of a magnet?
Go to page **355**.

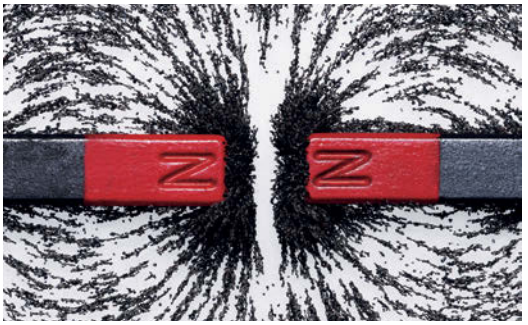


Figure 4 Two like poles repel the iron filings in their magnetic field.

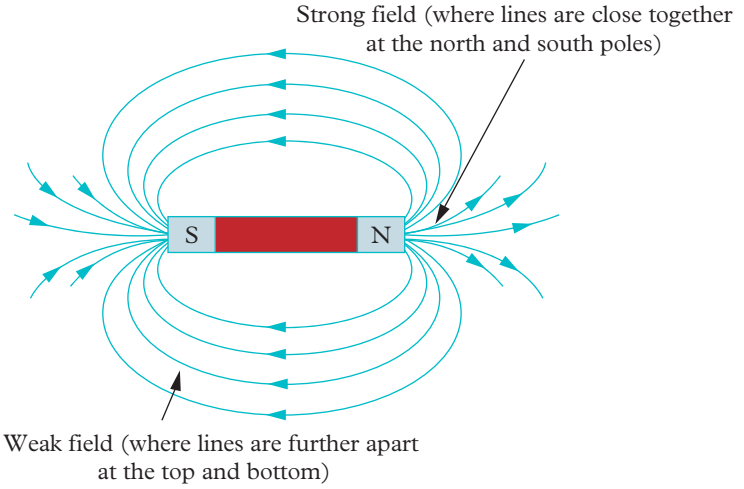


Figure 5 The magnetic field lines show that the field is stronger where the lines are closer together. The field is weaker where the lines are further apart.

What causes a magnetic field?

According to magnetic domain theory, magnets have regions called **domains**. In each domain, the atoms all line up in the same magnetic direction. There are many domains in materials with magnetic properties. But unless the domains all line up to point in the same direction, the material will not be magnetic. This is because the domains cancel each other out when they are facing in different directions.

An iron needle can become a magnet by sliding a strong magnet along one side of it in one direction. The strong magnet lines up the domains of the needle in the same direction as the magnetic field. Each time you stroke the needle, it causes more of the domains to point in the same direction. When most of the domains are pointing the same way, the needle becomes magnetic and can pull or attract a metal pin. Dropping the needle can cause the domains to become mixed up again.

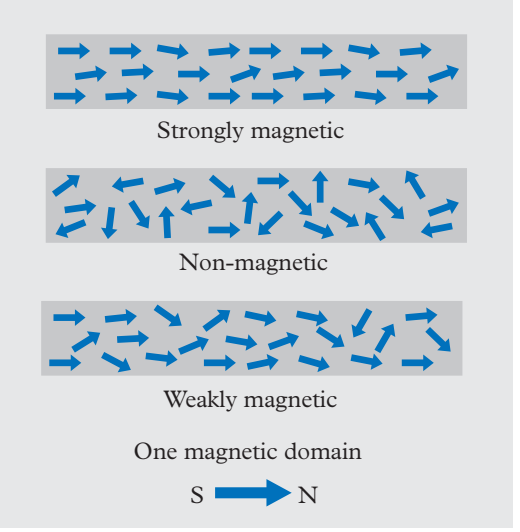


Figure 6 The magnetic domain theory

domain
a very small section of a magnet

Check your learning 3.1

Recall and explain

1 **Identify** three places where you might find a magnet.
2 **Explain** why a magnetic force is considered a non-contact force.
3 **Define** the term 'field'.

Apply and analyse

4 **Predict** what happens when the following poles of two magnets are pushed close together.
- **a** N and S
- **b** N and N
- **c** S and S

5 Draw the magnetic field around the bar magnets shown in Figure 4.
6 Draw how you might arrange bar magnets to spell your name. Label the north and south poles of the magnets.

Skills builder: Planning investigations

7 Using what you've learnt in this topic, suggest a method to create your own magnet out of an iron needle.
- **a** **Identify** a list of materials that you will need. (THINK: Are these materials or equipment easy to access?)
- **b** **Outline** a step-by-step process to create your magnet. (THINK: Is this method clear for someone else to follow? Number each step in the order it needs to be carried out.)

3.2 Magnetic fields are used in our daily lives

In this topic you will learn that:

- magnets are used in everyday life and technology, such as compasses and bankcards
- electromagnets use electricity to create a magnetic field.



Figure 1 A compass uses the Earth's magnetic field to point north.

Magnets are found in technologies we use every day, although we may not realise it at first. For example, did you know that there are magnets in your fridge door to make sure it closes properly?

Compasses use the Earth's magnetic field

A compass needle is a weak magnet. It has north and south poles. When a compass is placed near a strong magnet, the compass needle points in the direction of the field. You can see this by moving a compass around the sides and ends of a bar magnet. The north pole of a compass always points to the south pole of a magnet.

There is a magnetic field around the Earth. A compass needle will line up with the Earth's magnetic field. The part of the compass needle with the 'N' on it points to the north magnetic pole of the Earth. As unlike poles attract each other, it means the north pole of the compass and the south pole of the Earth's magnet attract each other. Therefore, the north magnetic pole is actually the south pole of the Earth's magnet. It is important to note that the 'geographic' North Pole of the Earth is not the same as the magnetic north pole. They are both in the Arctic Circle but hundreds of kilometres apart.

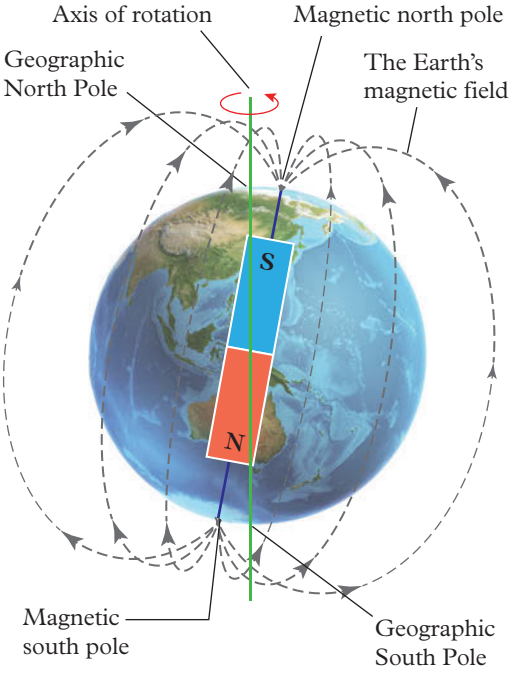


Figure 2 The Earth's geographic poles are not in the same place as its magnetic poles.

The North Pole, also known as the geographic North or true North Pole, is the northernmost point of Earth. If you tunnelled through the Earth from the North Pole in a straight line, you would come out the other side at the South Pole. The magnetic north pole is quite different. The magnetic north pole is not a fixed point – it moves about according to the magnetic field of the Earth.

Bankcards and magnets

You use magnetic fields in your daily life. The black strip on the back of a bankcard has a series of small magnetised zones separated by demagnetised zones. You can see these zones if you sprinkle fine iron filings on them. The iron filings arrange themselves according to the magnetic field surrounding the magnetic zones, which look a bit like a bar magnet. When the card is swiped through a card reader, the magnetic bar code is read and the person's name, their bank and account number are decoded.

The information on the black strip on a bankcard can be changed if it is put next to a strong magnet. Some stores also attach magnetic security devices to their stock to protect against theft. They remove these using a demagnetiser near the cash register. Leaving a bankcard on a store demagnetiser will also change the magnetic strips on the card.

Electromagnets

An **electromagnet** uses electricity to create a magnetic field. It is made by wrapping a coil of wire around an iron rod called a solenoid. When electricity flows through this wire, it creates a magnetic field. The more electricity running through the electromagnet, the stronger the magnetic force. Unlike permanent magnets, we can change the strength of the magnetic field according to our needs. Electromagnets can provide stronger magnetic fields than a permanent magnet and can be switched off and on. However, they need a constant source of electricity.

Many everyday technologies use electromagnets. You'll find electromagnets in speakers, microphones, doorbells or the electric locks on a car door.

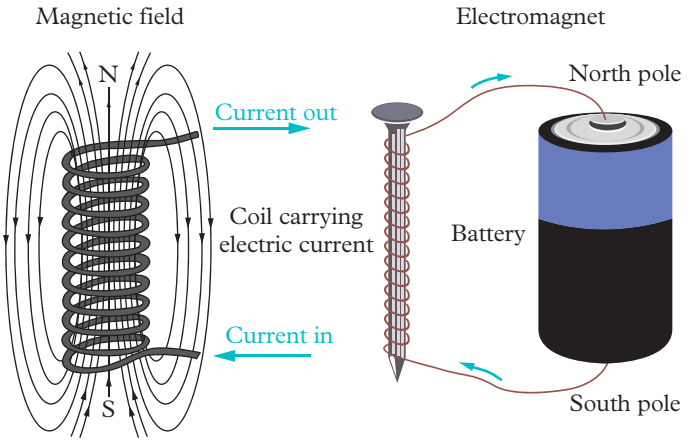


Figure 3 An electromagnet has a north and south pole, but it is created by electricity.

Electromagnets in speakers

Speakers use electromagnets to turn electric currents into something you can hear. To do this, an electromagnet is placed next to a permanent magnet inside the speaker. As electricity is passed through the coil of the electromagnet, its magnetic field changes. This means that it is repelled and attracted to the permanent magnet, creating vibrations as it switches back and forth. These vibrations are what make the sounds we hear.

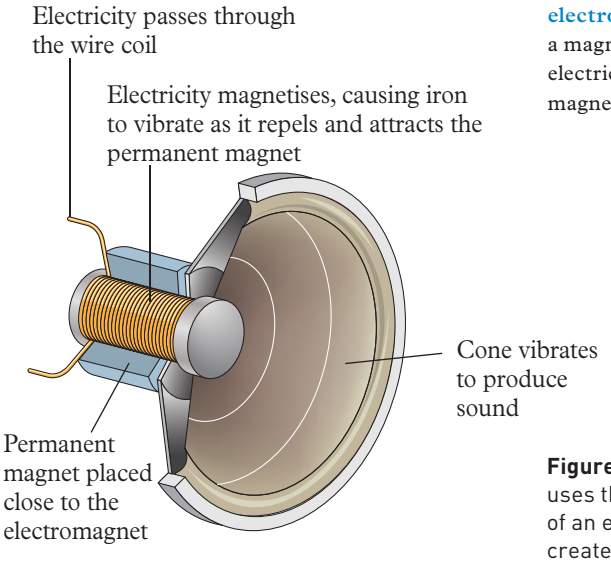


Figure 4 A loudspeaker uses the changing field of an electromagnet to create sound vibrations.

electromagnet
a magnet that uses electricity to create a magnetic field

Check your learning 3.2

Recall and explain

1 **Describe** how the field around a magnetic nail is mapped.

2 In words, **describe** the shape of the magnetic field when two magnets are:
- **a** attracting
- **b** repelling.

3 **Explain** how a compass works.

Apply and analyse

4 **Explain** how you can use a compass to determine the north and south poles of a magnet.

5 **Predict** what would happen to an electromagnet if the electricity source was removed.

6 **Explain** why you should never leave a library card on the demagnetiser at a shop's cash register.

Evaluate and create

7 **Investigate** one other everyday object that uses electromagnets. **Summarise** its purpose and how it uses electromagnetic fields.

Skills builder: Conducting investigations

8 Imagine that you have been asked to conduct an investigation to test the strength of an electromagnet that is made out of a nail, a copper wire and a battery.
- **a** **Assess** the risks that you might encounter using this equipment. (THINK: What could go wrong?)
- **b** Suggest ways to reduce each of the risks you have identified. (THINK: What can you do to make sure you are safe when you are using this equipment?)

3.3 Electrostatic forces are non-contact forces

In this topic you will learn that:

- objects can gain electrostatic charges by rubbing against other objects or by touching a charged object
- like electrostatic charges repel, and unlike electrostatic charges attract.

What are electrostatic charges?

Have you ever rubbed a balloon on your hair and seen the hair cling to the balloon? This is a result of a force called **electrostatic force**. When two atoms rub against each other, a small electrical charge builds up.

electrostatic force
a force between two objects caused by a build-up of negative charges

proton
a particle in an atom with a positive charge

electron
a particle in an atom with a negative charge

Atoms have positively charged (+) particles called **protons** and negatively charged (–) particles called **electrons**.

When two objects rub against each other, some electrons will move from one object to the other. When this happens, one object can end up with more electrons, making it negatively charged. The other object has fewer electrons, which makes it positively charged. These two charges act like the north and south poles of a magnet. The positively charged objects are pulled, or attracted, to the negatively charged objects. The unlike charges attract. Rubbing the balloon on hair causes the hair to become positively charged and the balloon to become negatively charged. When the (negatively charged) balloon moves away, the (positively charged) hair is still attracted to it. The hair lifts up and tries to cling to the balloon.

Figure 1 When the negatively charged balloon moves away, the positively charged hair is still attracted to it.



The rules of electrostatic forces are:

- unlike charges attract
- charged objects attract uncharged objects
- like charges repel.

Van de Graaff generators

A Van de Graaff generator works in the same way as rubbing a balloon on hair. In the long shaft of the machine, two long belts rub against one another, making the rounded dome of the machine positively charged. Negative charges are attracted to the dome. If anything comes close enough to the dome, the negative charges are attracted and jump through the air. You might see this as a spark.

It is not just negatively charged objects that are pulled, or attracted, to the dome. Uncharged objects are also attracted to the positively charged dome. If you stand too close to the Van de Graaff generator, your uncharged hair might be attracted to the dome.

Anything touching the dome also becomes positively charged. The girl in Figure 2 is standing on a rubber mat so that the negative charges cannot move from the ground into the dome. This means that she becomes positively charged like the dome. Just like the forces in a magnet, the like charges repel one another, making the strands stand on end.



Figure 2 This girl has become positively charged, like the dome of the Van de Graaff generator that she is touching. The strands of her hair are repelling one another.

INVESTIGATION
3.3: What if a balloon was electrostatically charged? Go to page **356**.

Electrostatic forces in everyday life

You may have experienced electrostatic forces when you were jumping on the trampoline or dragging your feet on carpet. Every time you jump, your feet rub against the trampoline mat. This causes a charge to build up in your body (charging by friction). When you touch someone else, or the framework of the trampoline, you may feel the spark as the negative charges from your body move to the frame of trampoline.

Cars

A build-up of electrostatic charge can occur on cars as they drive along the road. It is this charge that can cause explosions when filling up at a petrol station. If the driver gets out of the car without touching the metal of the car, the car can still have the positive charges built up. It is usually safe to start filling up the car; however, if the driver gets in and out of the car when the petrol fumes are in the air, the negative charges can be pulled between the car and driver. This causes a spark.

Lightning

Lightning is another example of electrostatic forces that we may observe in everyday life. In storm clouds, water droplets in warm air rising from the ground rub against ice crystals in cold air. These collisions cause static electricity to build in the cloud. Heavier negative charges sink to the bottom of the cloud, leaving positive charges at the top.

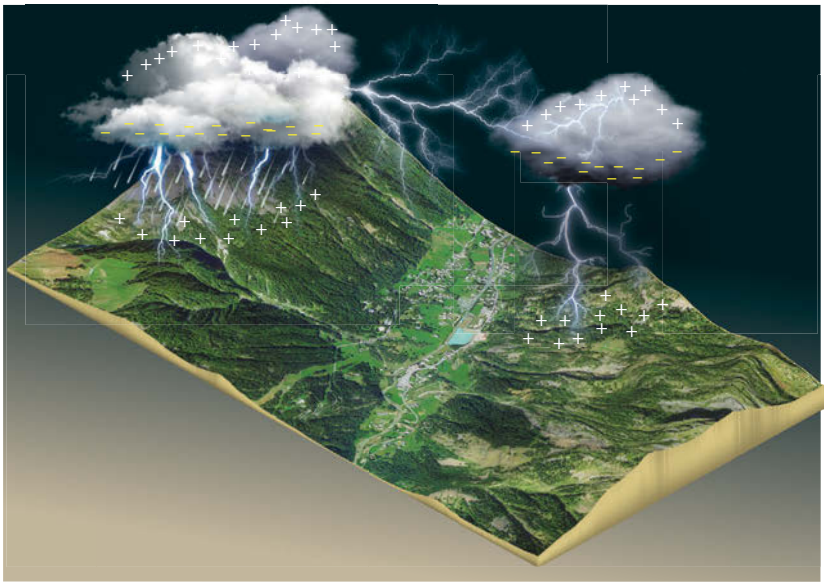


Figure 3 Lightning occurs when there is a sudden transfer of electrons.

If the charges grow large enough in the cloud, a bright flash of lightning occurs between the two charges. This sudden flow of electrons from one charged object to another is called **electrostatic discharge**. Lightning mainly occurs between charges in the clouds, but it can also occur between clouds and the ground. Figure 3 shows how the electrostatic charge in clouds can be attracted to the oppositely charged ground.

Volcanic eruptions and dust storms can also create lightning when particles of ash or dust collide in the air. Like the particles in clouds, ash or dust particles rub against each other and build up charge, which is released as electrostatic discharge.

electrostatic discharge the sudden transfer of electrostatic charge between two objects

Check your learning 3.3

Recall and explain

1 **Explain** why electrostatic forces are non-contact forces.

2 **Describe** how electrostatic charges can be created.

3 **Identify** the correct terms to finish these statements.

- **a** Unlike charges _____.
- **b** _____ charges repel.
- **c** Charged objects _____ uncharged objects.

Apply and analyse

4 When it is about to rain, ice crystals in clouds rub against one another and an electrostatic charge forms. **Outline** how this causes lightning.

5 Isaac was leaving the carpeted library to go home. When he touched the door handle, he received an electric shock. **Explain** why this happened.

Evaluate and create

6 **Investigate** how electrostatic discharge can play a role in dust storms or volcanic eruptions. Present your findings using an appropriate text type of your choice.

- **a** What text type would you use to present this information? (THINK: What format would be most interesting to your audience?)
- **b** What would your presentation need to include to make your explanation easy to understand?

Skills builder: Communicating

7 Imagine that you need to explain to a group of your classmates how lightning works.

3.4 Earth's gravity pulls objects to the centre of the Earth

In this topic you will learn that:

- gravity is a non-contact force and pulls everything towards the centre of the Earth
- weight is a measure of the force of gravity on an object.

We experience the effects of gravity every day. When you throw something in the air, the force of Earth's gravity pulls it back to the ground.

What is gravity?

weight
a measure of how much gravity is pulling on an object

mass
how many particles or atoms make up an object; the mass of an object does not change

gravitational field
the area around a body in which another body experiences a force of attraction

In the 17th century, a young student named Isaac Newton was sitting under an apple tree when an apple fell onto the ground. 'Why did it fall?' he wondered. There was nothing he could see that could push it or pull it. He realised that there must be a force that pulled the apple towards the Earth. This is prompted Newton to come up with the idea of gravity, or so the story goes.

Gravity is the force that attracts an object to the centre of the Earth. This happens to people, animals and objects on the surface of and nearby the Earth. Consider Figure 1. If everyone in the picture dropped an object, that object would fall towards the centre of the Earth.

As gravity is a non-contact force, it acts in a field called a **gravitational field**. There is a gravitational force between every two objects. The larger the mass of the objects, the stronger the force of gravity between them. Even you and the objects around you attract each other with a weak gravitational force, but it is too weak to notice. The Earth is made up of enormous amounts of matter and therefore its gravitational field is much stronger than your own. The direction of the Earth's gravitational field is always towards the centre of the Earth. So all objects in the Earth's gravitational field are pulled towards the centre of the Earth.

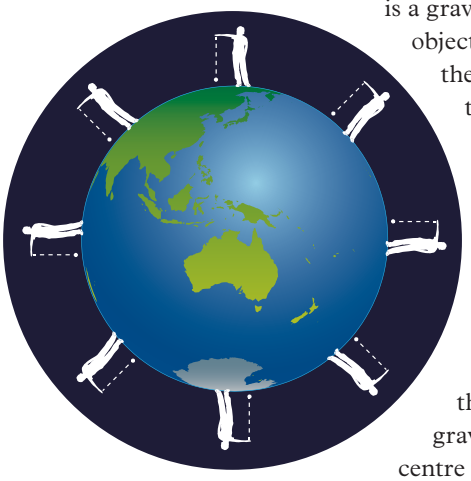


Figure 1 Gravity pulls objects to the centre of the Earth.

The Moon is made of less matter than the Earth. This means that the Moon's gravitational field is much weaker than the Earth's. An astronaut jumping on the Moon will be able to jump much higher than on Earth. This is because the Moon does not have as strong a pull force as the Earth.

The difference between weight and mass

Weight is a measure of how much gravity pulls on an object. Your weight on the Moon would be less than that on Earth. This does not mean you are smaller. It just means gravity is pulling you down less. Because weight is a measure of force, it is measured in newtons (N).

If weight is a measure of the force of gravity, how do scientists describe the amount of matter of an object? **Mass** (measured in kilograms) is the term used to describe how many particles or atoms make up an object.

The mass of an object doesn't change, no matter where in the universe it is. If a brick has a mass of 1 kilogram on Earth, it has this mass everywhere. However, the weight of brick will change. For example, on Earth, the brick may weigh 9.8 newtons, but on a large planet like Jupiter it would weigh 23.6 newtons.

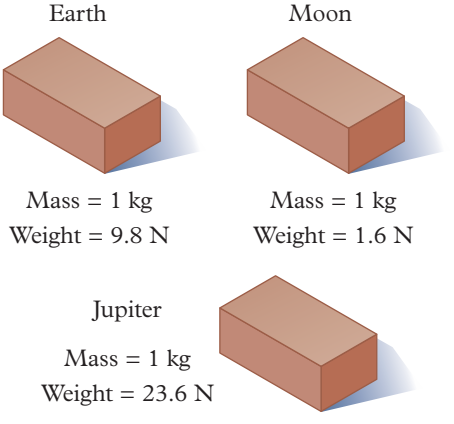


Figure 2 The mass of a brick doesn't change, but its weight is affected by gravity.

SKILLS LAB
3.4: Calculate weights in the solar system
Go to page **356**.

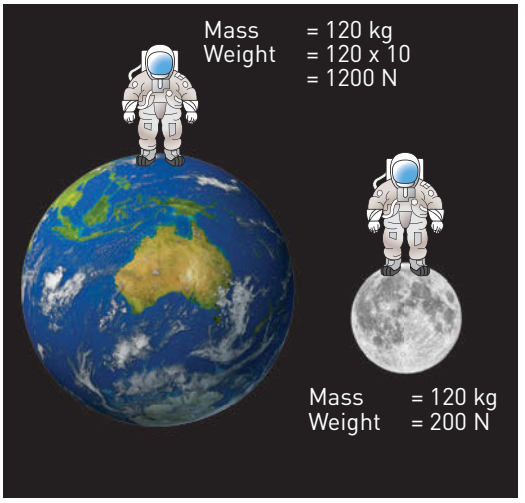


Figure 3 A person who wants to weigh less could go to the Moon.

On the Moon, the brick it would weigh approximately 1.6 newtons because the Moon is small and has less gravitational pull.

Gravity changes

As you move away from the Earth, the gravitational force slowly decreases. This means if you stood on a chair, your weight would have decreased slightly. Most scales will not be sensitive enough to measure this small change. However, if you stood on the top of Mount Everest, you would be several kilometres further from the centre of the Earth. As a result, your weight (the amount of pull force the Earth exerts on you) is 0.25 per cent less than if you were at sea level.

Gravity is not the same for every object. Objects with a larger mass experience a greater weight force due to gravity than objects with less mass. A 3 kilogram bowling ball therefore feels a stronger pull of gravity than a basketball that weighs about 600 grams. Does this mean the bowling ball will fall faster than the basketball?

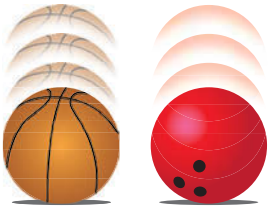


Figure 4 A bowling ball has more mass than a basketball. Although gravity pulls more on the bowling ball, they both fall at the same speed.

Check your learning 3.4

Recall and explain

1 **Describe** the difference between mass and weight.

2 True or false? The pull of gravity is stronger on an elephant than on a feather.

3 True or false? There is no gravity in space.

4 **Describe** how to measure the weight of an object.

Apply and analyse

5 A student performed an investigation to study the effect of mass of an object on its weight.

The results of the student's experiment are shown in the table.

Mass (kg)	Weight (N)
1	10
2	20
3	30
4	40
5	50

a **Identify** the dependent and independent variables.

b **Construct** a suitable graph to show the data in the table.

c Using your graph, **predict** the weight of an object with a mass of 7 kilograms.

d **Propose** a method to perform this investigation.

Evaluate and create

6 Building a settlement on the Moon has been suggested several times since Neil Armstrong first walked on the Moon. **Evaluate** the advantages and disadvantages of building such a structure in a low-gravity environment.

Skills builder: Questioning and predicting

7 Imagine that you are asked to compare how fast a basketball and a bowling ball fall to the ground when they are dropped from different heights (see Figure 4).

a Complete the scientific question for this investigation. (THINK: What variables are you measuring?) How does _____ affect _____?

b Check your question against the following:

i Is it testable? (THINK: Is it possible to design an investigation to test this question?)

ii Is it specific? (THINK: Would someone know what you wanted to investigate just by reading your question?)

iii Is the answer to this question based on opinion?

3.5 Gravity can act as an unbalanced force

In this topic you will learn that:

- gravity is an unbalanced force when it causes objects to change speed or direction.

Gravity can act in a number of ways as an unbalanced force. It can:

- slow down or change the direction of motion of objects
- cause falling objects to accelerate.

Gravity in everyday situations

When a book is lying still on a table, the forces acting on it are balanced. The table pushes upward on the book and gravity pushes downward. It does not move anywhere, and it does not change its shape. But if the book is picked up or dropped, it is changing speed and direction. The forces acting on it must be unbalanced.

For example, you might notice unbalanced forces when riding a bike. You have to pedal harder to get up a steep hill. This is because you are working against gravity by going up a slope. When you ride down a hill, gravity is on your side and will speed you up unless you apply your brakes (friction).

When a ball is thrown into the air, you have to apply force. Otherwise it will just fall to the ground. In Figure 1, a ball is thrown into the air. After throwing the ball into the air, gravity is the only force acting on it. The more force applied when it is thrown, the higher the ball goes. Once the ball has been released, no more upward force can be put on it. As the ball moves against the gravity, the gravity slows it down. Gravity then causes the ball to change direction and return to the ground.



Figure 1 What happens to a ball when it is released, versus when upward force is applied when it is thrown?

Skydiving and gravity

When a person skydives, the gravity forces acting on them are unbalanced at first. That is, from the moment a skydiver jumps from a plane, gravity immediately acts on them, pulling them toward the Earth. But is gravity the only force acting here?

While falling, the skydiver picks up speed. This causes air resistance to increase, slowing the skydiver down. Air resistance is a force that opposes the motion of an object in the air. It is like friction: its direction is always opposite of the direction of motion. Eventually the forces of air resistance and gravity become balanced, so the skydiver falls at a constant speed. When a skydiver's parachute opens, the air resistance acting on the skydiver increases even more. This slows the skydiver down until a constant speed is reached again.



Figure 2 Gravity works on a skydiver as they fall towards the ground.

Check your learning 3.5

Recall and explain

1 **Describe** air resistance.

2 Using an example, **explain** how gravity can act as an unbalanced force.

Analyse and apply

3 **Construct** a force diagram to show how gravity acts as a balanced or unbalanced force when:

- **a** a ball is on the ground
- **b** the ball is dropped from a height.

4 How does air resistance impact on a skydiver as they fall to the ground?

5 Catherine threw a ball as hard as she could toward the sky. **Explain** why the ball does not just keep travelling upward.

Skills builder: Processing and analysing data

6 **Analyse** the graph in Figure 3.

- **a** What information is this graph showing? (THINK: Use the graph's title and labels to help you.)
- **b** **Describe** what happens to the speed variable over time. (THINK: What patterns or changes can you see?)
- **c** **Suggest** what time the parachute opens. (THINK: What happens to the variables at this point on the graph? Why could this be?)
- **d** **Explain** what forces are acting at 50 seconds. (THINK: What do you know about forces that could explain this phenomenon?)

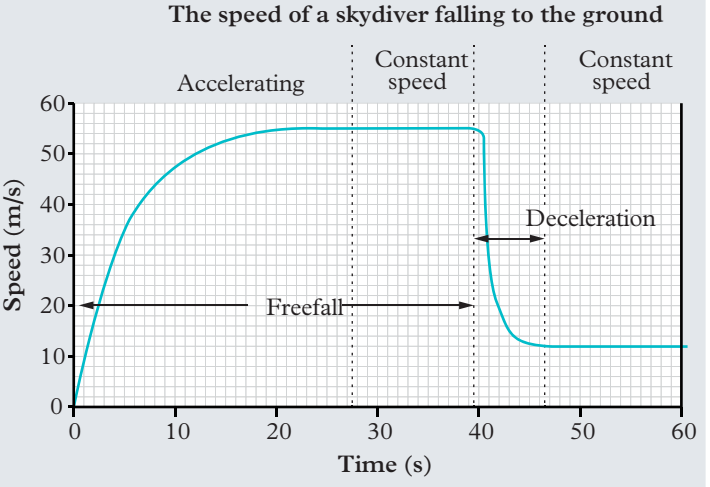


Figure 3 What information does this graph show?

REVIEW

Multiple choice

1 What is a field?
- **A** A non-contact force
- **B** The area where a force acts
- **C** A contact force
- **D** The area where no force is acting

2 If the magnets in Figure 1 are pushed together, they will:
- **A** repel
- **B** attract
- **C** remain where they are
- **D** move sideways.



Figure 1 Magnets

3 How could a balloon obtain electrostatic charge?
- **A** By sitting near a television
- **B** By spinning in the air
- **C** By rubbing against hair
- **D** By filling with salt water

Recall and explain

4 **Describe** the difference between a field and a force.

5 Draw a diagram of magnetic field lines around the bar magnets shown in Figures 2 and 3. Label the poles.



Figure 2 Iron filings show the magnetic field of a single bar magnet.

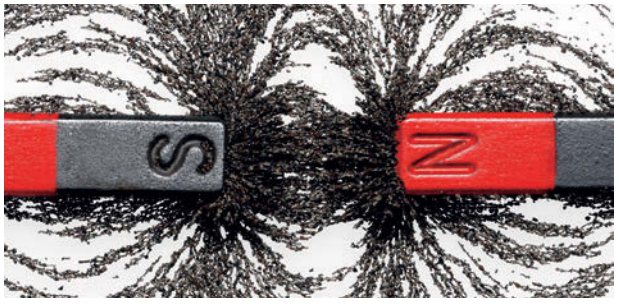


Figure 3 Two unlike poles attract the iron filings to each other in their magnetic field.

6 What is a gravitational field? How does the gravitational field of the Sun affect the planets?

7 Your mass at a given time remains the same, regardless of gravity. Your weight, however, changes as a result of gravity.
- **a** Why isn't the mass of any object changed by gravity?
- **b** Why does the weight of an object sometimes change?

8 **Explain** how an electromagnet works.

9 **Explain** what makes a compass point to the north magnetic pole.

10 **Explain** why the hair of a person touching a Van de Graaff machine may be standing up.

Apply and analyse

11 **Distinguish** between mass and weight?

12 **Compare** electrostatic charges with poles of a magnet.

13 Your teacher gives you two magnets; one of the magnets has its north and south poles written on it. **Explain** how you can determine north and south poles of the other magnet without using a compass.

14 Imagine life on the Moon. Write a paragraph describing how your day would have been different if you lived on the Moon. Which actions would be easier? Which actions would be harder or impossible?

15 When skydivers step out of a plane, they begin to fall towards the Earth. What causes this?



Figure 4 Skydivers falling toward the Earth

16 An adult male elephant has a mass of 7000 kilograms. **Predict** the mass of the elephant if it was:
- **a** in your bedroom
- **b** on top of Mount Everest
- **c** on the Moon
- **d** swimming in the ocean.



Figure 5 An elephant swimming in the ocean

17 An astronaut performed an experiment to compare the weight of an object on different planets. The object's weights were 16, 37, 248, 6.6 and 98 newtons on the Moon, Mars, Jupiter, Pluto and the Earth respectively.
   - **a** Present the results of this experiment in a table.
   - **b** Draw an appropriate graph to show the above results.
   - **c** **Identify** the planet with the strongest gravitational field.
   - **d** **Identify** the planet with the least mass.

Evaluate and create

18 All planets of the solar system orbit the Sun.
   - **a** Determine if the force/s acting on the planets are balanced or unbalanced. **Justify** your answer.
   - **b** **Identify** the force that causes the Moon to orbit the Earth.

19 You are slightly shorter at the end of the day than when you wake up in the morning. In a small group, design an experiment to test this hypothesis. Conduct the test over a series of days. Compile your results and compare your group's results with those of other groups in the class. As a group, come up with a conclusion for this experiment that draws on your knowledge of gravity.
   - **a** Was your experiment successful?
   - **b** Did your group work well together?
   - **c** How would you change your experiment next time?
   - **d** **Evaluate** your own contribution to this experiment and give yourself a score out of 5 (5 being 'excellent'; 1 being 'needs improvement') for:
     - **i** cooperating with other members of the group
     - **ii** listening to other group members
     - **iii** being reliable
     - **iv** doing your homework.

20 Write a creative short story (400 words) called 'A day without gravity'. You might begin by listing the main activities in your day, and then considering how they are affected by gravity. Incorporate as many examples into your story as possible.

Critical thinking

21 If the Sun is so much bigger than the Earth, why are we not pulled towards the Sun? **Propose** a possible explanation.



Figure 6 The Sun and the Earth

22 A basketball and a bowling ball have different masses; however, if you drop them from the same height at the same time, they will hit the ground at the same time. Why do you think this is?

23 If you dropped a feather and a bowling ball from the same height at the same time, the feather takes longer to land on the ground. Why do you think this is?

Going further

24 **Explain** in terms of forces how a water rocket works.

25 You have learnt two methods to charge objects. **Investigate** a different way in which an object can acquire electrostatic charge.

26 Imagine that you've been asked to design a skateboard that hovers off the ground, instead of using wheels. **Apply** your understanding of magnetic fields to design a skateboard that will hover.

27 **Justify** why all electrical appliances in Australia have a wire that connects their casing to the earth.

Research

28 Choose one of the following topics on which to conduct further research. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your findings in a format that best fits the information you have found and understandings you have formed.

» Maglev trains

The push forces of magnets are used in the design of futuristic Maglev (magnetic levitation) trains. A series of electronic magnets on the train and tracks suspend the train above the tracks. There is no contact between the train and the metal track. To make the train move, the driver changes the pole of the magnet and the train moves forward. Investigate how the Maglev trains work using magnets.

» Gravitational fields

Gravitational forces can be different in different locations around the world. For example, gravitational force is not the same at the Earth's poles compared with at the equator. Find out why.

» Electromagnets in medicine

Medical devices such as MRI machines use electromagnets. MRI stands for magnetic resonance imaging. Investigate what MRIs are used for, and how they use electromagnets to work.

Reflect

Now that you've completed this chapter, reflect on your ability to do the following:

	I can do this.	I can't do this yet.
Use the term 'field' in describing forces acting at a distance.	☐	☐ Go to page 44–45.
Identify ways in which objects acquire electrostatic charge.	☐	☐ Go to page 48–49.
Describe the behaviour of charged objects when they are brought close to each other.	☐	☐ Go to page 44–45 and 48–49.
Investigate everyday situations where the effects of electrostatic forces can be observed, e.g. lightning strikes during severe weather and dust storms.	☐	☐ Go to page 48–49.
Identify that the Earth's gravity pulls objects towards the centre of the Earth.	☐	☐ Go to page 50–51.
Describe everyday situations where gravity acts as an unbalanced force.	☐	☐ Go to page 52–53.
Distinguish between the terms 'mass' and 'weight'.	☐	☐ Go to page 50–51.
Describe the behaviour of magnetic poles when they are brought close together.	☐	☐ Go to page 44–45.
Investigate how magnets and electromagnets are used in some everyday devices or technologies used in everyday life.	☐	☐ Go to page 46–47.

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ENERGY

What is energy?

Have you ever wondered ...

- Where does energy come from?
- How does electricity provide light?
- What is happening when you double bounce someone on a trampoline?

4

SCIENCE UNDERSTANDING

In this chapter you will learn how to:

- identify objects that possess energy because of their motion (kinetic) or because of other properties (potential)
- describe the transfer of heat energy by conduction, convection and radiation, including situations in which each occurs
- relate electricity with energy transfer in a simple circuit
- construct and draw circuits containing a number of components to show a transfer of electricity
- investigate some everyday energy transformations that cause change within systems, including motion, electricity, heat, sound and light.

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4.1 There are different types of energy

In this topic you will learn that:

- energy is the ability to do work
- there are different types of energy, including light energy, heat energy, electrical energy, kinetic energy and sound energy.

Every time something moves, heats, stretches or changes, energy is being used. Energy is the ability to do work. It's not just lights and cars that use energy. All objects have energy.

Light energy

Light energy is essential to our lives and people have invented lots of devices to help us see in the dark. The humble electric light bulb revolutionised the world. Oil and gas lamps were popular in the old days and a torch helps us see at night when we go camping.

light energy
a form of energy, or electromagnetic radiation, that is visible

solar cell
used to transform sunlight directly into electrical energy; usually in the form of a panel; also known as a solar panel

The main reason life exists on Earth and not on other planets is because our atmosphere allows the right amounts of the different forms of electromagnetic radiation coming from the Sun to reach the surface. Plants rely on the light and heat from the Sun to make their own food and, in turn, to provide food for animals.

We are now trying to capture the light energy as efficiently as plants do. The relatively recent invention of **solar cells** to turn light from the Sun directly into electricity is now used to power many devices, such as calculators, street lights and cars.



Figure 1 We use energy to walk and carry things.



Figure 2 Kerosene lamps were used for many years before the invention of electricity.



Figure 3 Sunlight is essential for all the Earth. Without it, it is doubtful whether life would exist.



Figure 4 Solar-powered speed signs help save energy and are becoming common all across our country.

The best source of light is, of course, our Sun. Light energy is one type of energy that our eyes can usually detect. It moves in small packets of energy called photons. We see a range of colours (red, orange, yellow, green, blue and violet) in the visible spectrum, but the light we see is part of a larger group that is called **electromagnetic radiation**. This large group includes ultraviolet light, microwaves and X-rays. The study of light energy is known as optics.

Heat energy

Heat energy is more scientifically known as **thermal energy**. It can be generated by friction, such as by rubbing your hands together or by rubbing tyres on the road. Heat energy is also commonly generated by burning chemicals or by electrical devices. We experience heat energy being transferred from a high temperature place to a lower temperature place as we heat up or cool down. For example, an ice block feels cool because it takes the thermal energy away from our hands.

thermal energy
scientific term for heat energy

electromagnetic radiation
a form of energy that can be released into space by stars, including visible light, infrared radiation (radiant thermal energy), X-rays and gamma rays

Electrical energy

Electricity is a form of energy that comes from the flow of electric charge. **Electrical energy** powers lots of important objects in our lives, such as from lights and fridges to phones and televisions. Society has become reliant on electricity to go about our day-to-day lives. We use electricity in our homes, hospitals and supermarkets and at schools. We even rely on electricity to power the traffic lights that control traffic. Can you imagine living without WiFi or a phone? These things rely on electrical energy.

Sound energy

Have you been at a very loud concert and stood near the huge speakers? If so, you will remember that you not only heard the deep bass sound but also felt it in your body. You can feel the same vibrations in a car if you put your hand on the dashboard when the sound system is on full blast. Sound is made when things vibrate. Every time you make a sound – whether you are playing a musical instrument, speaking, singing or even whispering – you are making vibrations. This is called **sound energy**. Vibrations are simply tiny movements back and forth. They can occur in gases, liquids and solid things such as speakers – even the desk in front of you. Energy is needed to make sound. For example, unless



Figure 5 The heat of a 'burn-out' creates great clouds of smoke.

a drummer uses energy to hit the drums, the drum skin will not start to vibrate and will not make a sound.

Kinetic energy

The energy of movement is more scientifically called **kinetic energy** (KE). Whenever objects or people move, they have kinetic energy. The most common way we think of kinetic energy is when we see a moving object. A moving car has kinetic energy. The faster the object is moving, or the more mass the object has, the greater the kinetic energy. Even objects that are too small to be seen, such as atoms, have kinetic energy.

electrical energy
energy associated with electric charge, either stationary (static) or moving (current)



Figure 6 Sound energy is carried through the vibrations in guitar strings.

kinetic energy
the energy possessed by moving objects

sound energy
a type of kinetic energy made when things vibrate

Check your learning 4.1

Recall and explain

1 **Describe** what energy is.
2 **Outline** five different types of energy.
3 **Recall** another name for heat energy.

Apply and analyse

4 **Assess** how important energy is for transport.
5 You push two similar toy cars and they both start moving. However, one moves faster than the other.
   a **Determine** the type of energy they have.
   b **Determine** which car has more energy. **Account** for your answer.

Evaluate and create

6 **Investigate** the ultimate source of all energy. **Justify** your response.
7 **Discuss** how a guitar produces sound energy.

Skills builder: Planning investigations

8 **Propose** the type of information you think should be collected for each of the following investigations: first-hand or secondary sources.
(THINK: Can you design an investigation to test the question? If not, you may need to get information from a secondary source.)
   a Which state produces the most solar energy in Australia?
   b Which solar panel produces the most electrical energy?
   c Which remote control car has the most kinetic energy?

4.2 Potential energy is stored energy

In this topic you will learn that:

- potential energy is stored energy in an object
- there are different types of potential energy.



Figure 3 This television has GPE when raised above the ground.

potential energy
energy that is stored in objects

Potential energy is energy that is stored in objects and waiting to be used. This stored energy can be the result of a change of shape (stretching or squashing) or an object's height above the ground. This energy can be stored in many forms.

Elastic potential energy

gravitational potential energy
energy stored due to the height of an object, e.g. a child at the top of a slide

elastic potential energy
energy stored through stretching or squashing, e.g. in a stretched spring or rubber band

A trampoline has the ability to 'store', or hold, energy for later use or if conditions change. The springs and the mat of the trampoline stretch under our weight and hold this stored energy. The more they stretch, the more energy they hold. The energy is returned to our bodies when the springs and mat return to normal and throw us into the air. Energy that is stored through stretching or squashing is called **elastic potential energy**. Elastic potential energy is the energy stored in an object that has changed in shape.



Figure 1 Poweriser jumping stilts rely on elastic potential energy.



Figure 2 Pogo sticks release the elastic energy of springs to provide motion.

Gravitational potential energy

Gravitational potential energy (GPE) is the energy stored in an object that is high above the ground. If we lift an object to a height, it gains GPE. The larger the mass and height, the more GPE the object gains. Have you ever noticed that falling a greater distance produces a greater 'thud' and can hurt more? This is because of the amount of GPE. As an object falls, the object's GPE can be transformed into other forms of energy. This happens when a person plays on a slide at the playground. The higher they climb, the more GPE they get. When they slide down, the GPE decreases. The person gains kinetic energy. They may also feel the friction of the slide as heat or even as a zap of static electrical energy.

Chemical potential energy

After we have done a lot of exercise, we often crave foods that we believe will restore our energy levels. These foods, usually sweet things, release stored chemical energy really quickly to satisfy our cravings. All foods have some energy stored in them, but the difference is how quickly the energy can be released.

Fuels, such as natural gas and petrol, provide us with energy too. A Bunsen burner uses the burning of natural gas to provide heat for laboratory experiments. Petrol has chemical energy stored in it, as do explosives and batteries. These devices all contain **chemical potential energy** that can be released when we need it. Chemical potential energy is the energy that is stored in any chemical.



Figure 4 Energy drinks contain chemical potential energy.



Figure 5 The energy released from a nuclear explosion is much, much greater than that from other types of explosions.

chemical potential energy
energy stored in chemicals, e.g. in food, fuel or explosives; also known simply as chemical energy

Nuclear energy

Nuclear potential energy involves the reaction at the centre of atoms. When atoms react in chemical reactions, they usually release only small amounts of energy. However, if the centres or nuclei of those atoms can be made to react, the amount of energy released is much, much larger. In fact, the amount of energy released is so huge that it can cause massive amounts of destruction.

nuclear potential energy
energy stored at the centre of atoms

Check your learning 4.2

Recall and explain

1 **Identify** four examples of devices or situations that involve potential energy.
2 **Identify** what type of energy is stored in a battery.
3 We get our energy from the chemicals in food. **Identify** the type of energy this is.
4 **Describe** four devices, other than those mentioned already, that possess elastic potential energy.

Apply and analyse

5 **Describe** how a person might use a bow to shoot an arrow. **Identify** the type of energy used in this process.
6 You throw two similar balls into the air. One ball reaches a height of 2 metres and the another reaches a height of 5 metres before returning to the ground.
   a **Determine** the type of energy that the balls have when they are at their maximum heights.
   b Which ball has more energy at its maximum height. **Account** for your answer.

Evaluate and create

7 Nuclear energy is used throughout the world, but it is not used in Australia. **Investigate** three countries that use nuclear power to generate electrical energy.

Skills builder: Problem solving

8 **Evaluate** the following claim: 'Nuclear energy is good for the environment.'
   a **Investigate** the advantages and disadvantages of using nuclear energy by using secondary resources to fill in a PMI table like the one below.
   b Using your PMI table, **assess** the above claim. (THINK: Do you think this claim is correct, somewhat correct or incorrect? What evidence do you have to support this?)

Plus (THINK: What are the benefits?)	Minus (THINK: What are the problems?)	Interesting (THINK: What else should be considered?)

4.3 Energy can be transferred and transformed

In this topic you will learn that:

- energy cannot be created or destroyed
- energy can be transferred and transformed.

Energy cannot be created or destroyed. When energy is passed from one object to another, it is said to be **transferred**. There are different types of energy. When energy is changed from one form to another form, it is said to be transformed.

transferred
said of energy that has moved from one object to another

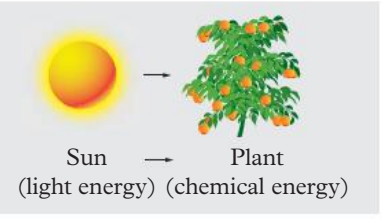


Figure 1 The transfer of energy from the Sun to a plant

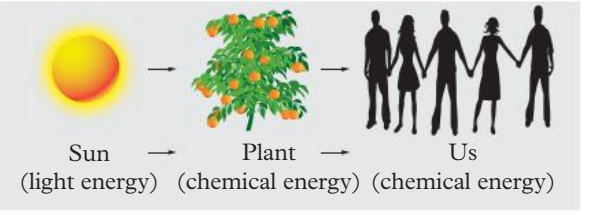


Figure 2 The transfer of energy from the Sun to people

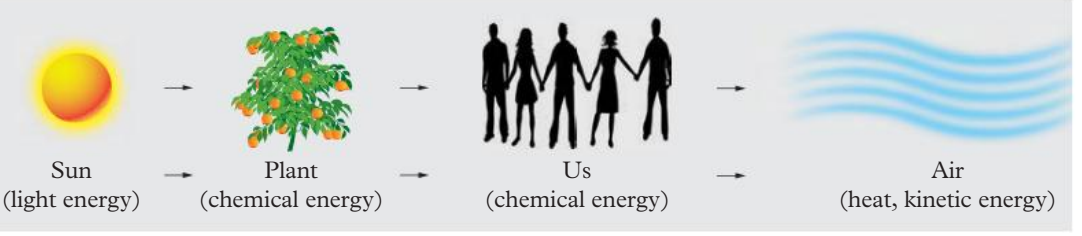


Figure 3 Using energy to move, like walking, warms the air around us.

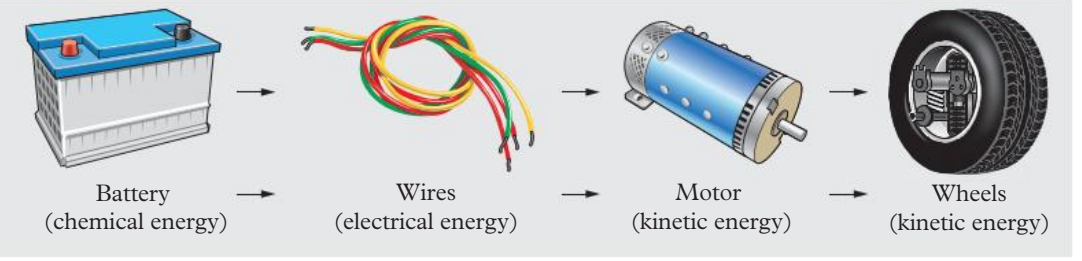


Figure 4 Chemical energy transforms into kinetic energy in a car.

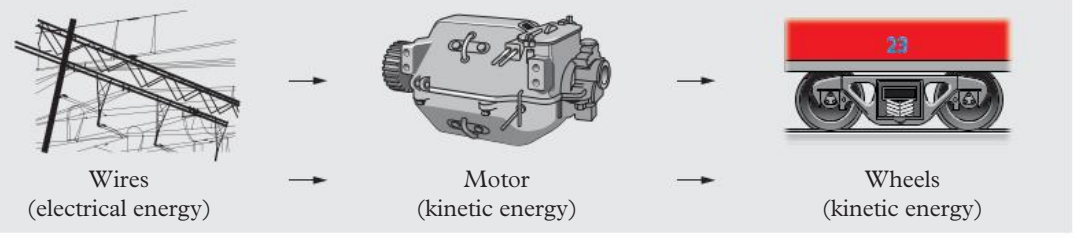


Figure 5 Electrical energy transformation to power a train

SKILLS LAB
4.3: Drawing flow diagrams of energy transfer
Go to page **358**.

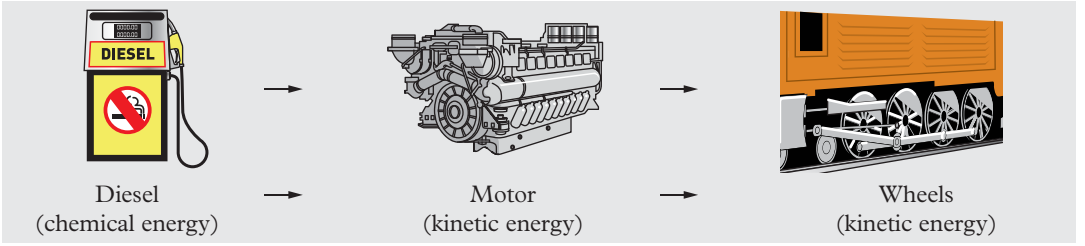


Figure 6 Chemical energy transformation to power a train

Energy transformation

Energy transformation refers to the way energy changes from one form to another. For example, the chemical energy in diesel or petrol can be transformed into kinetic energy when it is used in a car. The electrical energy that powers a microwave can transform into heat (thermal energy) to warm our food. These are all energy transformations because one type of energy is transformed into a different form.

Where does energy come from?

We have all felt the energy of the Sun on a hot day. It can warm our skin and even cause sunburn. Plants are very efficient at absorbing the energy of the Sun. The light energy is transferred from the Sun to the plant. This can be shown using a flow diagram (Figure 1). The plant transforms the energy in a process called photosynthesis into chemical energy, which it needs to live and grow. Eventually, animals (including humans) eat the plants and the energy is transferred again (Figure 2).

We use the energy for moving, including walking. This also produces heat that then warms up the air immediately around us (Figure 3).

Electric cars are being designed to use the energy stored in batteries, rather than petrol, to power an electric motor that makes the wheels turn. This process of this energy transfer and transformation is shown in Figure 4.

Public transport uses energy too. Metropolitan trains and trams transfer electrical energy from overhead wires into the motor that makes the wheels move.

Trains that travel to regional areas usually run on diesel fuel and don't need overhead electrical wires. The engines in these trains burn diesel fuel, transferring energy into movement into the wheels via the motor (Figure 6). Ships and planes use a similar process in their engines.

Energy flow diagrams

Interactive
Energy transformations

Although we cannot see energy transformations, they can be represented visually using flow diagrams. Arrows are used to illustrate the direction of the change from one type of energy to another. The energy input is written at the beginning of the arrow and the energy output is written at the end (the point) of the arrow. For example, when you turn on a light bulb, the energy is transformed from electrical energy to light energy. This can be written as:

Electrical energy → light energy

energy transformation
the conversion of energy from one type into another (e.g. in a toaster, the main energy transformation is from electrical to heat)

Although we focus on one main energy output of a transformation, there can be more than one. These other minor energy outputs are called **by-products**. For example, when you turn on a light, the main energy output is light energy. However, you may also find that some heat energy results from this transformation. This heat energy is a by-product, but it can also be referred to as wasted energy.

by-product
a secondary, sometimes unintended, product from a process

Not all energy transformations are simple. Sometimes there are several energy transformations in a row to get the final energy output. This is called an energy chain. For example, if you want to listen to music or a podcast on your phone, there are a number of energy transformations that need to take place. The chemical energy in your phone's battery needs to be converted into electrical energy. This electrical energy can then be transformed into kinetic energy in your phone's speakers as vibrations. These vibrations can transform into sound energy, which is the final output in the energy chain.

Figure 7 An energy flow diagram

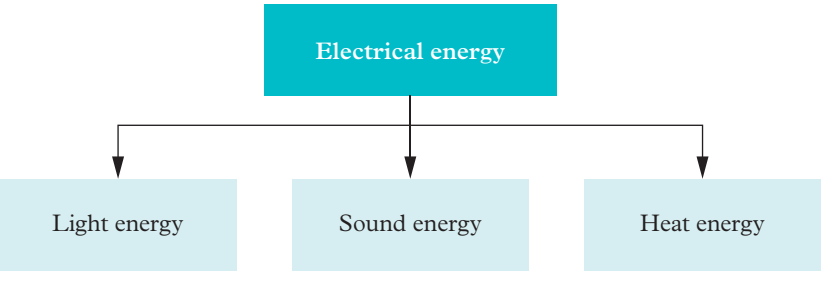




Figure 8 Metropolitan trains transfer energy from overhead electrical wires. This energy is transformed into kinetic energy in the motor that moves the train forward.



Figure 9 Headphones transfer energy in batteries to our ears as sound.

Energy transfers for entertainment

When you stream movies or listen to music, lots of energy transformations are taking place. The devices you use, such as a phone, laptop or television, need to transfer chemical energy from batteries to wires. If you're watching a movie, this energy needs to transform into electrical energy before it transforms into light energy that we can see and sound energy that we can hear. Energy transfers and transformations take place in many of the devices we use daily.

A mobile phone uses a speaker to produce the sound of a person's voice or the various ring tones and beeps that the phone makes. Home phones use a speaker too, as do televisions, radios, headphones and many other devices. They all transfer energy from the battery to the wires and then to the speaker to make sound.

A television remote control transfers energy from the device through the air as light and into the television set (see Figure 10). In fact, most remote controls use infrared light, which is the invisible type of light usually associated with heat. The remote control sends a pulse of infrared light that represents a particular command, such as to change the channel or increase the volume. An infrared light detector on the television receives the light signal and transfers it back into electrical energy, which then carries out the command.

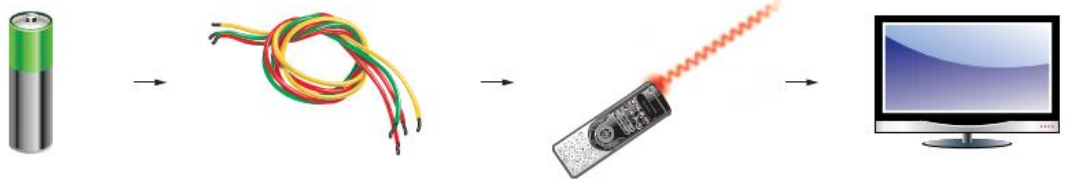


Figure 10 Energy transference from the battery of a remote control to a television



Figure 11 A mobile phone energy chain



Figure 12 The internal components of a mobile device transform energy.

Check your learning 4.3

Recall and explain

1 **Describe** the terms 'transfer of energy' and 'energy transformation'.

2 **Identify** the types of devices that the following flow diagrams represent.
- **a** Wires → motor → air
- **b** Battery → wires → light globe
- **c** Sun → muscles → bicycle

3 **Summarise** the entertainment devices mentioned in this section and draw flow diagrams for the energy transformations they perform.

4 **Explain** why the direction the arrows point in a flow diagram are important.

Apply and analyse

5 **Identify** an example of an energy transformation that outputs:
- **a** heat
- **b** motion
- **c** light
- **d** sound.

6 Construct a flow diagram to represent the energy transformation in the diagram below.

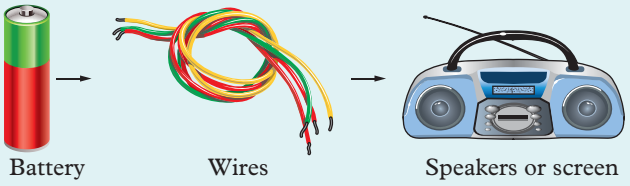


Figure 13 An energy transformation

Evaluate and create

7 **Construct** an energy flow diagram to track changes in energy from the solar energy to mechanical energy in a vacuum cleaner.

8 **Investigate** where the energy comes from in fuels such as petrol. Draw an energy flow diagram to **summarise** your findings.

Skills builder: Conducting investigations

9 Layla was asked to investigate how the chemical energy in a battery pack transforms to power a lightbulb. When she connected the light bulb to the power source, she observed the bright light energy that was released. Layla then decided to feel the light bulb to observe if it had released any heat energy.
- **a** **Identify** the safety risks in Layla's method. (THINK: Could any of the equipment, or how it is handled, be dangerous?)
- **b** Suggest how Layla might avoid the identified hazards.

4.4 Heat energy is transferred through conduction and convection

In this topic you will learn that:

- heat energy in solids transfers by conduction
- heat energy in liquids and gases transfers by convection.

Thermal energy moves spontaneously from a hotter substance to a cooler substance. This energy transfer is called heating, even though one substance is being cooled.

Heating by conduction

Heat transfer by **conduction** is the transfer of thermal energy from matter that is warmer to matter that is cooler. This happens spontaneously when two solid objects make direct contact with each other. Eventually the two objects reach **thermal equilibrium**, meaning that they no longer exchange heat energy because they have the same temperature.

Consider what happens when we heat a saucepan of water on a gas burner:

1. When the gas burns, thermal energy is released.
2. The hot particles in the gas flame move quickly and occasionally bump into the atoms of the relatively cold metal of the saucepan.
3. Energy passes to the slowly vibrating atoms in the saucepan so that they vibrate faster.
4. The quickly vibrating atoms in the saucepan bump into other nearby metal atoms, transferring energy to them. This heats the saucepan.
5. When the saucepan heats up, energy is transferred to the water inside it.

Although the energy moves through the metal of the saucepan and into the water, the atoms in the metal do not change their positions – metal atoms do not move into the water.

conduction
the transfer of thermal energy (kinetic energy of particles) through direct contact; the atoms do not change their position in the material

thermal equilibrium
when two systems are at the same temperature; no heat moves from one system to another

conductor
a substance that allows the movement of thermal or electrical energy

insulator
a substance that prevents the movement of thermal or electrical energy

Conductors and insulators

A thermal **conductor** is any material that allows thermal energy to flow easily through it. All metals are conductors, although some are better conductors than others. Thermal insulators are materials that slow down the transfer of thermal energy. **Insulators** such as socks, jumpers, flasks and blankets keep us warm in cold weather. They make it difficult for our 'body heat' to escape, insulating us against the cold. Insulation in the roof and walls of a house prevents heat gain and loss during summer and winter. So insulation can hold heat in or keep it out.

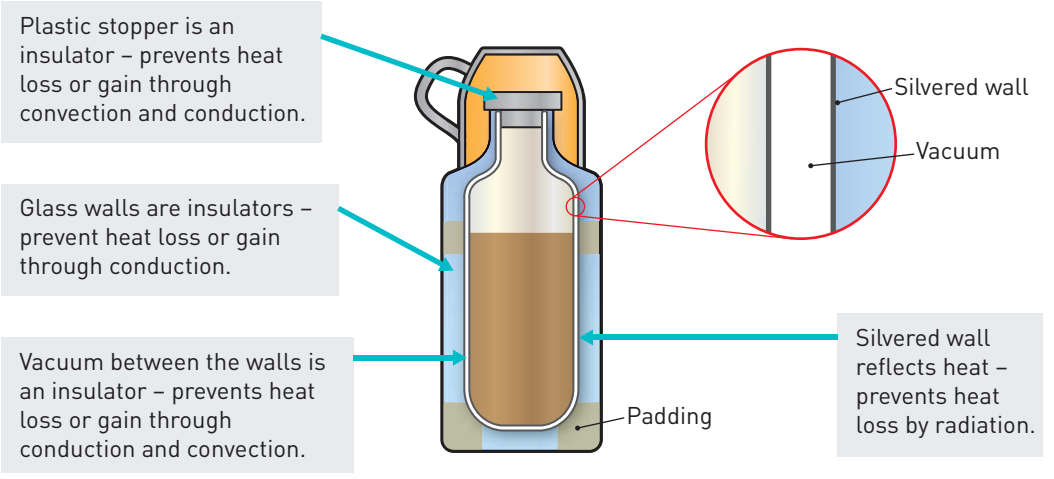


Figure 1 The structure of a vacuum flask is shown here. Vacuum flasks are designed to keep hot substances hot and cold substances cold. To do this they must prevent the contents from losing or gaining heat – conduction, convection and radiation must be minimised. Careful choice of materials and clever design make this possible.

Heating by convection

In liquids and gases, thermal energy transfers by **convection**. Tiny currents, called convection currents, carry the thermal energy. A **convection current** is a movement within a liquid or gas.

When we heat a saucepan of water on a gas flame, the following occurs:

1. Energy transfers by conduction from the hot saucepan to the water molecules that are touching the metal.
2. The water molecules in contact with the metal move faster than the molecules in the water above. Because they are moving faster, they take up more space. They are less dense.
3. As a result, the heated water molecules near the bottom of the saucepan begin to rise, leaving room for the cooler water molecules to take their place.
4. The heated water molecules take thermal energy with them as they move.

We heat liquids from below because most of the energy transfer in liquids (and gases) takes place by convection. This process happens in the air. For example, the Sun heats the ground and the warmed ground then heats the air next to it by conduction. The warmed air, being less dense than the cooler air above, rises, taking the thermal energy with it. This distributes the energy through a much deeper layer of air than could occur just by conduction from the ground. This process of convection in the air is what drives the weather on Earth.

convection
the transfer of thermal energy by the movement of molecules in air or liquid from one place to another

convection current
the current or flow of air or liquid that results from the transfer of thermal energy through convection



Figure 2 Convection currents are created in a saucepan of water when it is heated. The heated water molecules (shown in red) rise while the cooler ones (shown in blue) sink.

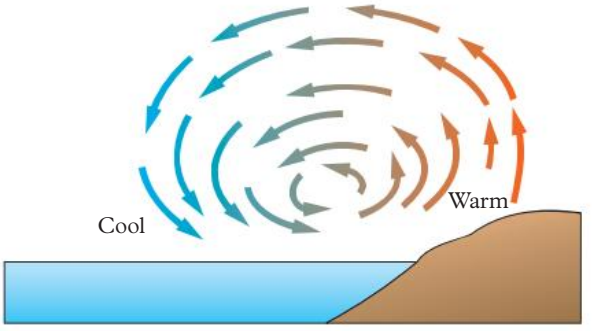


Figure 3 The circulation of air in a sea breeze

Check your learning 4.4

Recall and explain

1. **Identify** two examples of situations where thermal energy is transferred by:
   - **a** conduction
   - **b** convection.
2. **Identify** two examples where good thermal insulators and conductors are needed in everyday life.

Apply and analyse

3. Modern saucepans have a copper bottom, steel sides, a plastic handle and a glass lid. **Explain** why each of these materials is used for a particular part of each saucepan.
4. **Explain** why heat energy cannot be transferred in solids by convection.
5. **Construct** a labelled diagram to explain how heat energy transfers in water.

Evaluate and create

6. **Discuss** why you think that scientists are happy to refer to thermal energy transfer as heating, even though in every case something is being cooled.

Skills builder: Processing and analysing data

7. Harriet measured the temperature of a pot of water as it heated over 6 minutes. Her results are shown in the table

Time (min)	Temperature (°C)
0	20
1	25
2	40
3	55
4	70
5	82
6	95

   - **a** **Identify** an appropriate type of graph to plot this data. (THINK: Is the data qualitative or quantitative? Is it continuous or discrete?)
   - **b** **Construct** your graph, including all labels and a title. (THINK: What are the variables in this investigation?)

4.5 Radiation transfers thermal energy

In this topic you will learn that:

- another way of transferring heat energy is radiation
- radiation of thermal energy can move through a vacuum (empty space).



Figure 1 In a household radiator, energy from the movement of particles becomes infrared radiation.

radiation
the transfer of thermal energy (via photons) across empty space or through another substance

When you go outside on a sunny day, you experience a particular kind of heating process. Energy transfers from the hot Sun at a temperature of about 6000°C to you at a temperature of 37°C. This is a different kind of heating process from conduction and convection. Conduction and convection both need the presence of a substance to transfer the energy and, in the process, the substance heats up. But the energy from the Sun travels across many millions of kilometres of space to reach the Earth. It then passes through the Earth's atmosphere, hardly heating the air in the atmosphere on the way through at all.

Radiation is the transfer of energy across empty space, or through another substance, without heating it. Radiation is not necessarily absorbed when it meets a substance – it may be reflected or transmitted. For example, radiation from the Sun is transmitted through the atmosphere, absorbed by the ground and reflected from the tops of clouds.

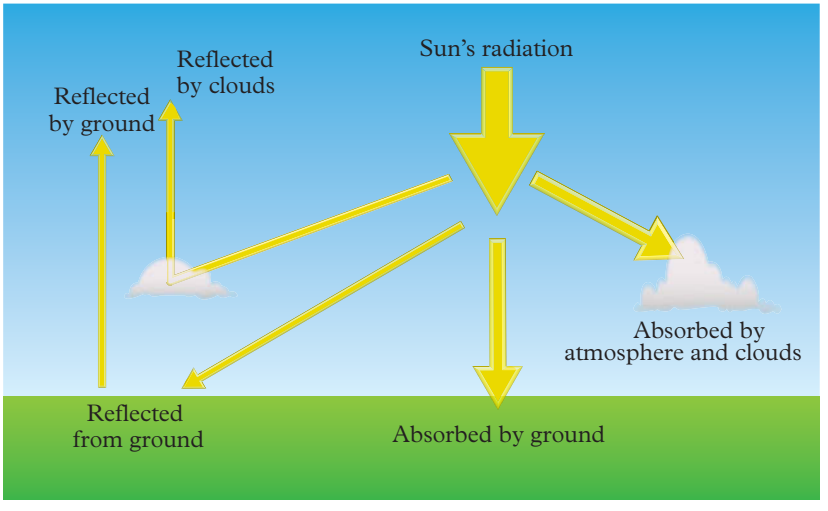


Figure 2 Radiation from the Sun does several things, depending on the weather conditions.

Any object radiates energy in one or more forms, depending on the temperature. An electric radiator radiates energy in the form of mainly infrared radiations. An incandescent globe radiates some visible light as well as infrared radiation. The gases that are found between the galaxies of our universe radiate microwaves or radio waves.

Radiation can be produced in ways other than by heating an object. For example, radio waves can be produced by a transmitter, and light can be produced in a fluorescent tube. The different forms of radiation have one thing in common – they can all be produced just by heating an object to the right temperature.

Deadly radiation heat

Being outdoors during a bushfire means you can be exposed to large amounts of radiant heat, even if the air around you is cold. The closer you are to the source of the fire, the more radiant heat you are exposed to and the hotter you feel. This heat travels in straight lines out from the bushfire. It can heat up objects so much that they spontaneously burst into flames before the fire has even reached the location.

Radiant heat can kill very quickly. Your body cannot absorb large amounts of radiation for very long, and the body's cooling regulation system cannot cope with the large amounts of heat that is generated.

The best protection is to put a barrier between you and the source of the radiant heat (such as bushfires). Concrete walls and buildings can absorb the radiant heat with little damage unlike windows, which will shatter, or rubber, which will melt. Cover all your skin, and wear sturdy boots, gloves and a hat. Cover your face with a mask or towel, and protect your eyes with goggles.

CHALLENGE
4.5: Protection from heat radiation
Go to page **360**.

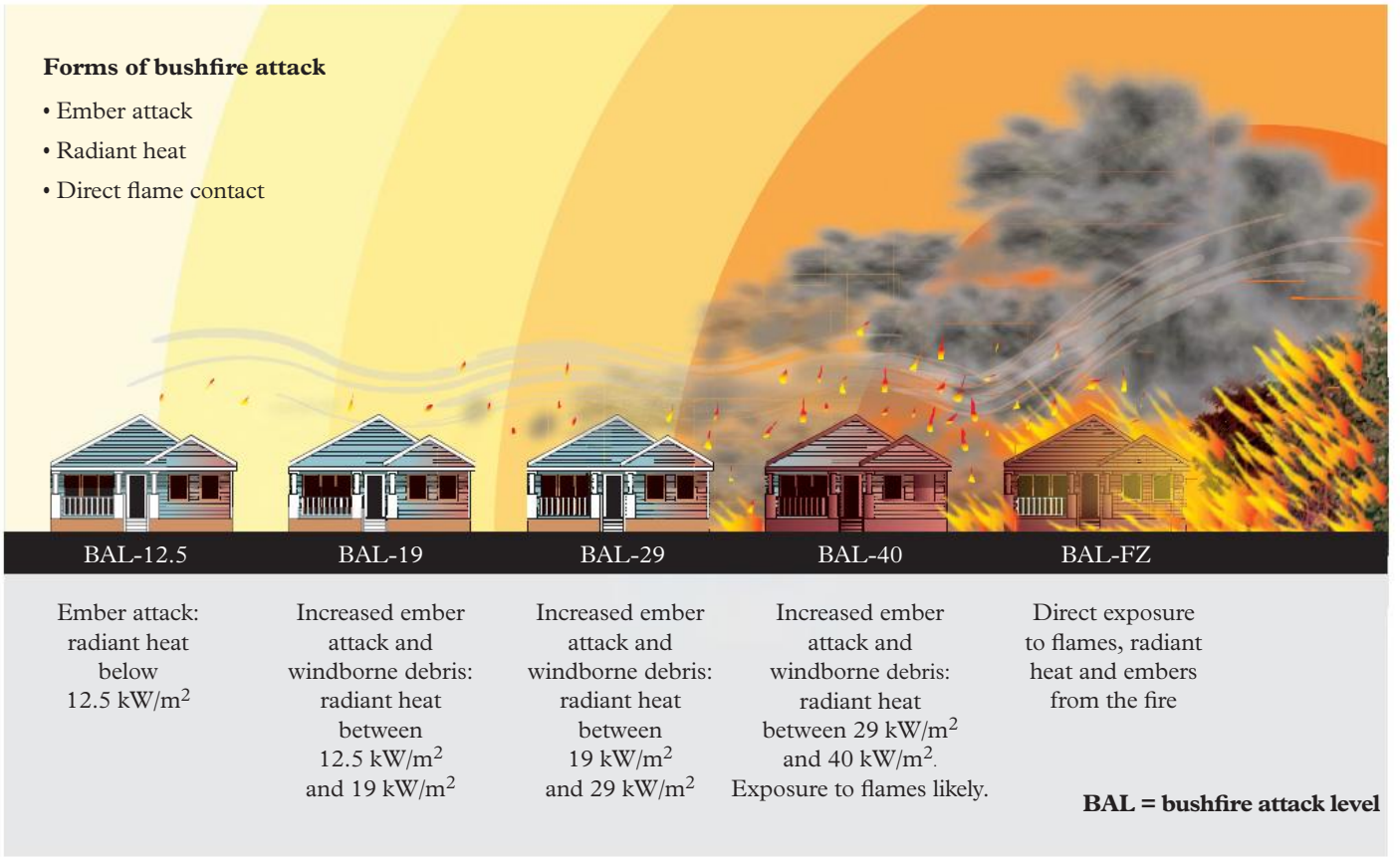


Figure 3 Bushfires radiate intense heat.

Check your learning 4.5

Recall and explain

1 **Describe** what radiation is.

2 List some examples of familiar devices that work by the movement of light, infrared radiation, microwaves or radio waves through space.

3 List some examples of familiar devices in which light, radio waves or infrared radiation are absorbed. **Describe** the effect(s) that this absorption produces.

4 **Describe** three possible pathways for radiation from the Sun.

Apply and analyse

5 **Distinguish** between radiation and convection and conduction.

6 **Identify** how heat energy transfers in the following scenarios.

- **a** A kettle gets hot when it is on a gas burner.
- **b** The water in the kettle gets warm when the kettle is on a gas burner.
- **c** You feel the heat when you sit next to an electrical heater.
- **d** The temperature goes higher when you turn on the air conditioner in winter.

Skills builder: Communicating

7 Communicate one key safety message about radiant heat during bushfires for the general public.

- **a** **Identify** what text type you will use to communicate your message. **Justify** why you have chosen this format. (THINK: Who is this message for? What text type would they most likely be interested in?)
- **b** **Construct** one or two sentences that you could use to get your message across quickly. (THINK: How would you explain it to people who haven't been in class to learn about radiant heat? Keep it simple, but make sure it is scientifically correct.)

4.6 Electricity is the presence and flow of electric charges

In this topic you will learn that:

- electricity is the transfer of electrical energy through a closed circuit
- an electric current results from the movement of negatively charged electrons around an electric circuit.

Electrostatic charge

electric charge
a positive or negative charge that is the property of subatomic particles that results in electrical energy

An **electric charge** can be positive or negative. It is produced by subatomic particles (parts of atoms) such as electrons, which carry a negative charge, or protons, which carry a positive charge. Objects are normally uncharged – their atoms usually have equal numbers of positive protons and negative electrons. But when two objects are rubbed together, electrons may be transferred from one object to the other. This causes the object with fewer electrons to become positively charged, and the other object with extra electrons to become negatively charged.

electricity
the transfer of electrical energy by flow of electric charges

Electricity is therefore the flow of electric charges.

Conductors and insulators

electrical conductor
a material through which charged particles are able to move

electrical insulator
a material that does not allow the movement of charged particles

An **electrical conductor** is a material through which charged particles are able to move. An **electrical insulator** is a material that does not allow the movement of charged particles. Most wires are made of a copper metal with a plastic coating around the outside. Copper metal is an electrical conductor as electrons are able to move through it easily. Plastic is an electrical insulator – the wires are coated in plastic to prevent the charge being 'lost' to the surroundings as it passes through the wires.

Electrical energy and circuits

electric current
the flow of electrical charge through a circuit

electric circuit
a closed pathway that conducts electrons in the form of electrical energy

The flow of electric charges from one place to another along a pathway made from an electrical conductor is called an **electric current**. An electric current comes from the movement of negatively charged electrons along a pathway called an **electric circuit**. For historical reasons, the direction of the current is given as the flow of positive charges from the positive terminal of the energy source to the negative terminal. This flow of positive charges is referred to as a conventional current (see Figure 1).

As electrons move around an electric circuit, they carry energy from the energy source (such as a battery) to the device that uses the energy (such as a light globe, motor or heater).

Electrical circuits must have an energy source, wires to carry the charges, and a load that transforms the electrical energy into heat, light or kinetic energy. Many devices have 'gaps' called switches to control the flow of electricity in a circuit. If the switch is open, the pathway is broken and no electricity flows. Circuits must therefore be closed for electricity to flow through them.

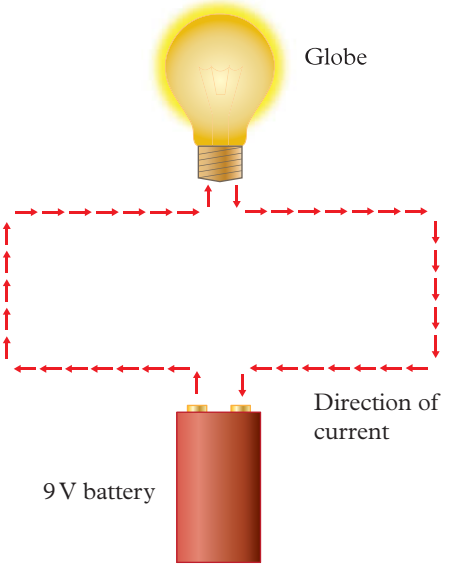


Figure 1 Conventional current in an electric circuit

CHALLENGE **4.6A:** Demonstrating electrostatics Go to page 361.

CHALLENGE **4.6B:** Making a simple torch circuit Go to page 361.

CHALLENGE **4.6C:** Connecting circuits Go to your obook.

Drawing circuit diagrams

Circuits and their components are represented by circuit diagrams. Rather than drawing a picture of the different devices, each component of a circuit is represented by a symbol (see Figure 2). The circuit illustrated in Figure 3a includes a globe, a battery, connecting wires, a switch and a meter, such as an ammeter, to measure the electric current. This circuit is represented in a circuit diagram in Figure 3b. Connecting wires are usually shown as straight lines; when they meet at junctions, they are often (but not always) joined at right angles. The longer line on the battery represents the positive terminal, and the shorter line represents the negative terminal. These terminals are where the wires are connected. When drawing a circuit diagram, you need to use a ruler and a pencil. All lines should be connected to indicate no breaks in the circuit.

An ammeter is a device that measures the current or flow of charges through the circuit. The ammeter counts the charges in packets called coulombs. The number of electrons that pass through the circuit is measured as coulombs per second, or amperes (A) – commonly called amps.

A voltmeter is a device that measures voltage, which is the amount of energy the electrons are transferring to the components. Voltage is measured in volts (V). To use a voltmeter, it must be connected around a component so that it can measure the difference in the energy of the electrons from just in front of the component to just after it.

When the components are connected in a line or row, it is called a series circuit. When the circuit has more than one pathway for the electrons to travel, it is called a parallel circuit.

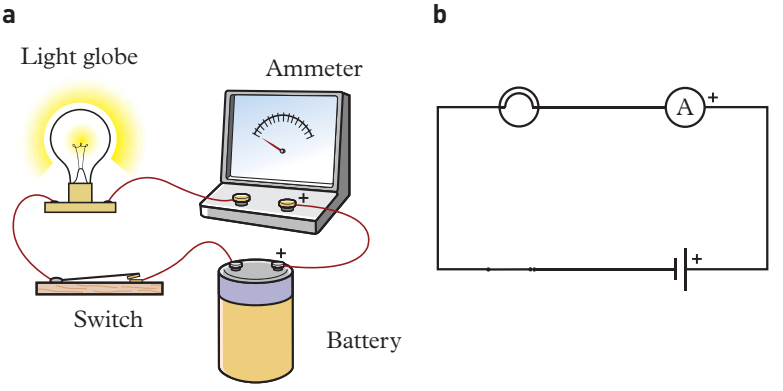


Figure 2 a A simple circuit; **b** a circuit diagram of the simple circuit

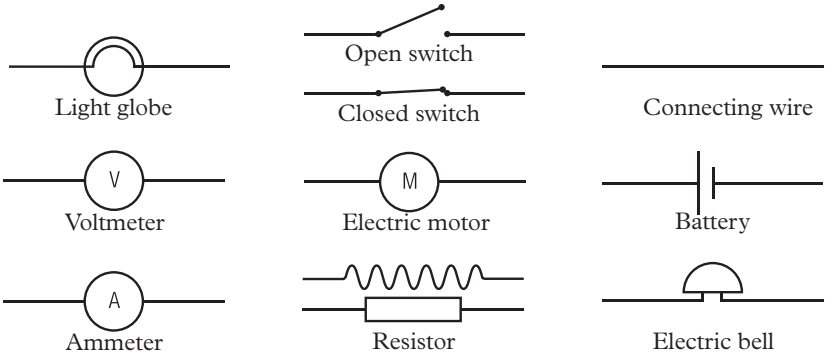


Figure 3 Some symbols used in circuit diagrams

Check your learning 4.6

Recall and explain

1 **Describe** what an electric circuit is.

2 **Recall** what travels through an electric circuit.

3 **Contrast** a conductor and an insulator.

Apply and analyse

4 **Construct** the following circuit diagrams.

- **a** Battery, light bulb, resistor and closed switch
- **b** Battery, light bulb and electric bell
- **c** Battery, connecting wire, open switch and ammeter

Evaluate and create

5 You have heard the statement 'Do not touch electrical appliances when your hands are wet'. **Account** for this statement.

Skills builder: Questioning and predicting

6 **Predict** what will happen to the flow of electricity for each of the following circuits in Figure 4. (THINK: Would anything stop these circuits from lighting up?)

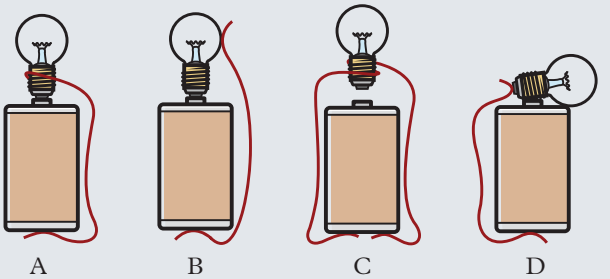


Figure 4 Electrical circuits

REVIEW

Multiple choice

1 **Identify** the correct definition for 'energy'.
- **A** The ability to heat or light things
- **B** The ability to do work
- **C** The ability to create movement
- **D** The flow of electricity through a circuit

2 What is an electrical conductor?
- **A** A material that charged particles can move through
- **B** A material that charged particles cannot move through
- **C** An object that powers an electrical circuit
- **D** An object that can open or close an electrical circuit

3 A pot of water that has been put on a stove transfers heat energy by:
- **A** elastic potential energy
- **B** radiation
- **C** convection
- **D** conduction.



Figure 1 Heat transfer on a stove

Recall and explain

4 Are the following true or false? For false statements, rewrite them to make them true statements.
- **a** Springs only hold stored energy when they are stretched.
- **b** When an object is thrown up in the air it gains gravitational potential energy.
- **c** Sound energy is a type of potential energy.
- **d** Petrol contains nuclear energy.

5 What is the main form of energy in each of the following situations?
- **a** Water flowing slowly over a waterfall
- **b** A rollercoaster at the lowest point of the ride
- **c** The Sun coming in through a window on a sunny day
- **d** A person riding a skateboard
- **e** A stretched rubber band



Figure 2 A rollercoaster at the lowest point in the ride

6 **Identify** a device that transforms:
- **a** electrical energy into light energy
- **b** elastic energy into kinetic energy
- **c** electrical energy into sound energy
- **d** gravitational potential energy into electrical energy
- **e** kinetic energy into electrical energy.

7 **Recall** a situation where you can see expansion due to heating of a solid, liquid or gas.

8 **Explain** why you might employ a chemical engineer if you were designing a new clothing range.

9 List the main parts of a circuit and **explain** the role of each part.

10 **Recall** the direction that the current flows in a circuit.

11 **Explain** how we can stop electricity flowing.

12 **Identify** the role of a switch in a circuit.

13 Match the circuit symbol with its name: globe, battery, ammeter, switch.

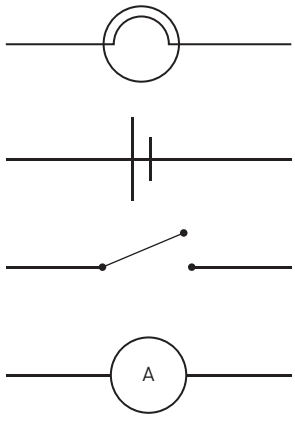


Figure 3 Circuit symbols

14 **Explain** why we need to put at least a load in an electric circuit.

Apply and analyse

15 The main job of a car travelling on the road is to produce kinetic energy in its wheels. **Identify** the other parts of a car that may demonstrate kinetic energy.

16 Think of your day today. How many different energy forms have you come across, possessed, used or witnessed? List them in order of use during the day. **Identify** which was the most common and **explain** why.

17 **a** **Identify** the three processes by which energy can be transferred by heating. Use a labelled diagram to **explain** each type.

b **Explain** which of these processes is happening when you touch something hot.

18 **Compare** conduction and convection.

19 Draw a circuit diagram for a circuit containing a battery, globe and closed switch.

20 Draw a circuit diagram showing a battery and an open switch, with a globe either side of the switch.

a Does it matter where in the circuit the switch goes?

b Show the direction of electron flow and the direction of conventional current.

21 Draw a circuit diagram to represent the circuit shown in Figure 4. Label the direction of the current.

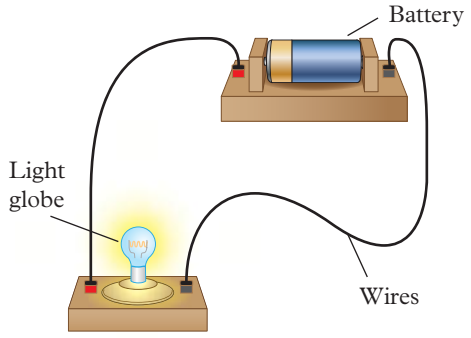


Figure 4 Electrical energy moves from the battery through the wires to the light globe.

Evaluate and create

22 Energy comes in many different forms. Create a poster to illustrate each type of energy with visual examples.

23 In some countries, double-glazed windows are used for heat and sound insulation. They consist of two sheets of glass with a thin gap between them. **Explain** how this makes them better insulators than other glass windows.

24 Visit a local playground and examine the play equipment. Take a digital photo or draw a picture of a piece of equipment, and work and identify the types of energy that are demonstrated as a child plays on the equipment.

25 Draw a circuit diagram for a torch that can be turned on and off by a switch. **Justify** why you have included each component in your diagram.



Figure 5 A torch turns on and off with a switch.

Critical thinking

26 **Consider** the energy transformations that would take place during a rollercoaster ride. **Construct** an energy flow diagram to represent these transformations.

27 **Discuss** why you think the electrical wires used in your house always have a plastic cover.

Going further

28 Design an experiment to **investigate** thermal conductivity of different material.

29 **Assess** the impact of the invention of electricity on people's life and the environment.

30 Energy types rarely exist alone. They are always on the move, making things happen. Think about some of the things energy can do. For at least two of these, **identify** the type or types of energy involved. If more than one type of energy is involved, link the different types with arrows. Try to include as many different scenarios as you can.

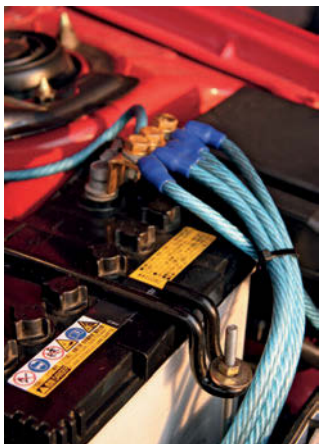




Figure 6 The chemical potential energy in batteries can be transformed into electrical energy to power almost anything.

Research

31 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions you would like to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting and who your audience might be.

» Biofuel

Biofuel is an alternative source of energy that comes from burning the energy stored in plants. Investigate what type of energy biofuel is. What kind of energy transformations might take place?

» Nuclear disaster

The massive earthquake and tsunami in Japan in March 2011 caused extensive damage to the Fukushima Daiichi Nuclear Power Plant, north of Tokyo, and created an emergency situation. Investigate this disaster. What are the issues surrounding the use of nuclear energy?



Figure 7 Rapeseed oil is a crop that is used to create biofuel.

Reflect

Now that you've completed this chapter, reflect on your ability to do the following:

	I can do this.	I can't do this yet.	
Identify objects that possess energy because of their motion (kinetic) or because of other properties (potential).	☐	☐	Go to page 58–61.
Describe the transfer of heat energy by conduction, convection and radiation, including situations in which each occurs.	☐	☐	Go to page 66–69.
Relate electricity with energy transfer in a simple circuit.	☐	☐	Go to page 70–71.
Construct and draw circuits containing a number of components to show a transfer of electricity.	☐	☐	Go to page 70–71.
Investigate some everyday energy transformation systems that cause change within systems, including motion, electricity, heat, sound and light.	☐	☐	Go to page 62–65.

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ENERGY EFFICIENCY

What makes something energy efficient?



Have you ever wondered ...

- Can energy be created or destroyed?
- What are star ratings on appliances for?
- Is using electricity bad for the environment?

5

SCIENCE UNDERSTANDING

In this chapter you will learn how to:

- identify that most energy conversions are inefficient and lead to the production of heat energy, e.g. in light bulbs
- research ways in which scientific knowledge and technological developments have led to finding a solution to a contemporary issue, e.g. improvements in devices to increase the efficiency of energy transfers or conversions
- discuss the implications for society and the environment of some solutions to increase the efficiency of energy conversions by reducing the production of heat energy.

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Check your Student obook assess for these digital resources and more:

QuizletLive
Compete in teams to test your knowledge.

Assess quiz
Before you start this chapter, assess your science skills.

Check your Teacher obook assess for these digital resources and more:

QuizletLive
Launch a quiz for your students on key concepts in this chapter.

5.1 Energy cannot be created or destroyed

In this topic you will learn that:

- the law of conservation of energy states that energy cannot be created or destroyed
- energy efficiency is a calculation of the percentage of useful energy transformed.

Law of conservation of energy

If all the input energy could be added up and compared with all the output energy, it would always be the same. The total energy remains constant, but the type of energy will change – what goes in must come out! This is considered the **law of conservation of energy**. No energy can be created or destroyed. The energy at the end must be equal to the energy present at the beginning.

When you lift an object up in the air, you are adding gravitational potential energy. This energy did not just appear. The kinetic energy of your hand was conserved and transformed into the gravitational potential energy of the object. When the object is dropped, the energy is not destroyed. The gravitational potential energy is once again transformed into kinetic energy.

law of conservation of energy
the scientific rule that states that the total energy in a system is always constant and cannot be created or destroyed

energy efficiency
the measure of the amount of useful energy transformed in an energy transformation process; usually expressed as a percentage of the input energy

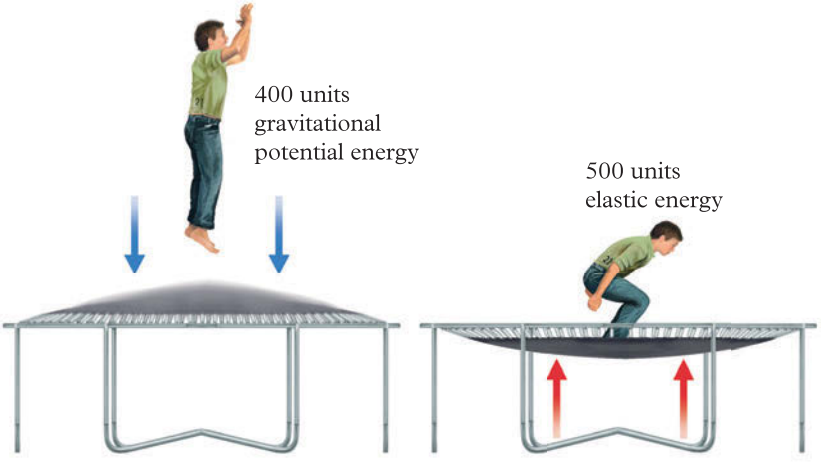


Figure 1 Five hundred units of energy are stored in the springs of the trampoline. At the highest point, the jumper has 400 units of gravitational potential energy. Where have the 100 'missing' units gone?

Energy efficiency

If a device like a trampoline transforms most of its input energy into the most useful output energy, it is considered to be a very energy-efficient device. The less 'wasted' energy, the more energy-efficient the device is. **Energy efficiency** is a calculation of the percentage of useful energy transformed:

$$\text{Efficiency} = \frac{\text{useful energy output}}{\text{energy input}} \times 100$$

Worked example

Calculate the energy efficiency of the trampoline in Figure 1 if the input energy was 500 units and the useful output energy was 400 units.

Solution

$$\text{Efficiency} = \frac{\text{useful energy output}}{\text{energy input}} \times 100$$

$$= \frac{400}{500} \times 100$$

$$= 80$$

The trampoline is 80% efficient, which is not too bad.

Scientists are constantly trying to design the best appliances possible with the highest efficiency ratings. This would make them better for the environment and cost less to power. Do you and your family always buy the most efficient appliances? Are you familiar with the star ratings on appliances? More stars mean that the appliance is more energy efficient. Not only is it good to know that less energy is being wasted, but it also means that, on your electricity and gas bills, you are paying for energy that is being used rather than for energy that is being thrown away.

Heat and sound waste energy

If no system is 100% efficient, but the energy cannot be destroyed, then where does the energy go? In most cases, the energy is transformed into heat and sound energy.

Think what happens when you drop a ball on the ground. The ball starts with gravitational potential energy, which is transformed into kinetic energy when you drop it. When the ball hits the ground it makes a noise. The larger the noise, the more sound energy that is generated. If you bounce a ball many times in a row, you might be able to feel the ball start to warm up. Heat energy is generated. Both the heat and sound energy dissipate into the air. They are not lost or destroyed. We cannot reuse them. They are by-products of the main energy transformation.

Energy in light bulbs

You and your family use electricity to light your house. Electrical energy flows through a light bulb and light your house. The light bulb mainly transforms electrical energy into light (useful energy) and heat (waste energy).

According to the law of conservation of energy, the amount of energy that goes in as electrical energy must be equal to the sum of output energies (light and heat). There are different types of light bulbs, such as incandescent light bulbs, fluorescent and LED light bulbs. Have a look around your school or home. What kinds of light bulbs are installed?

A lot of light bulbs, such as incandescent light bulbs, are considered energy inefficient because they produce a lot of heat energy. Fluorescent lights look like long glass tubes, and they are filled with mercury gas. These lights do not generate much heat compared with incandescent light bulbs.

Compact fluorescent lights (CFLs) are another energy-saving alternative to incandescent lights. The CFLs use less energy than the filament bulbs and last much longer. Light-emitting diodes (LEDs) are even more energy efficient. They produce very little heat, so a much higher percentage of the electrical energy that goes into the light is transformed into light energy.

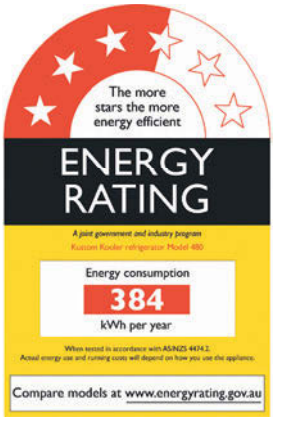


Figure 2 Appliances with a higher star rating are considered more energy efficient.



Figure 3 An incandescent light bulb produces light and heat energy.

Check your learning 5.1

Recall and explain

1 **Summarise** the law of conservation of energy.

2 **Define** the term 'energy efficiency'.

Apply and analyse

3 If you release a rubber band that had 10 units of elastic energy, 12 units of kinetic energy cannot be produced. **Explain** why.

4 For the rubber band in question 3:
- a **Calculate** its percentage efficiency if 7 units of kinetic energy was produced.
- b **Explain** where the remaining 3 units of energy have gone.

5 A LED light bulb transforms electrical energy into light energy, but it is not 100% energy efficient. **Identify** what happens to the wasted energy.

Evaluate and create

6 The Sun provides heat and light energy to our planet every day. If this energy is not destroyed, **explain** where it goes.

Skills builder: Planning investigations

7 Consider the following investigation.
- a What is missing from this investigation? (THINK: What other information would you need to know?)
- b What would you change to improve this investigation? (THINK: What could make this test more reliable or valid?)

Aim: To compare the energy efficiency of 2 different electric kettles of the same power rating.

Materials: 2 kettles (both with the same power rating, e.g. 2000 W), 500 mL measuring cylinder, thermometer, stopwatch

Method

1 Fill both kettles with exactly 500 mL of the same cold tap water.

2 Turn both kettles on at the same time.

3 Use the stopwatch to time how long each one takes to boil the water.

5.2 Energy efficiency can reduce energy consumption



Figure 1 A window awning

In this topic you will learn that:

- devices are designed to reduce energy consumption on a daily basis.

Knowledge of energy transformations is not just limited to scientists. A variety of people use this knowledge in their everyday lives.

Heating and cooling your house

No doubt your house has some sort of heating or cooling system, depending on where you live. You probably use electricity or gas to do this. In a hot environment, energy is needed to remove the heat from inside your home, allowing it to cool down. The warm air inside the house is moved over cool pipes in the air conditioner. The thermal energy of the house air is passed to the refrigerant inside the pipes and then carried outside the house. If the house is well designed, the thermal energy remains outside and the house stays cool.

Architects design homes to help control the flow of thermal energy. They can add a variety of features that help limit the amount of heating or cooling your house needs. As a result, it reduces the energy consumption as well as the electricity bill.

chemical engineer
an engineer who combines existing materials and develops new materials

mechanical engineer
an engineer who designs and improves machines



Figure 2 A veranda shades the walls and windows of a building from the Sun's heat.

Insulation

Lining the inside of the walls, floors and roof of your house can make sure that the heat is not transferred between the outside air and the inside of the house. This means you will keep the heat inside on a cold day, and outside on a hot day.

Window awnings

One of the main places heat is transferred is through a window. On a hot day, the light and heat from the Sun easily radiates through windows. This transfers the heat into the house. An awning on a window can limit this. Limiting the number of windows facing the Sun can also help prevent the heat being transferred into the house.

Verandas

A veranda works much like an awning, but it also prevents the heat and light from the Sun from shining on the walls. This prevents the heat from being transferred to the walls and then to the air inside.

Engineers help to make things more efficient

The word 'engineer' comes from the Latin words *ingeniator* or *ingenium*, which literally mean 'ingenious one'. Engineers provide solutions, shape future developments and generate ideas that make life easier. All engineers are problem-solvers, but some know how to solve specific problems better than others.

Chemical engineers combine existing materials and develop new materials. These materials can then help other engineers build structures. Chemical engineers would also consider where the materials come from, whether they were being used sustainably, and how much energy is required to process and transport them.

Mechanical engineers deal with forces and motion – designing and improving things that have moving parts or have physical forces pushing or pulling them. This includes large structures such as water slides where the gravitational potential energy at the top is used to provide kinetic energy (speed) at the slide's base. Reducing the friction of the slide makes it more efficient; therefore, more of the potential energy will be transformed into kinetic energy (speed) at the base. Mechanical engineers have produced some of the most important and useful inventions in history, including the zipper and the yo-yo!

Electrical engineers design and organise electric circuits and electrical equipment. This equipment may be used for satellites, computers and medical equipment. They are also involved in developing electricity supplies, such as renewable energy sources.

Civil engineers research, plan and design structures. They are interested in how different materials perform under different conditions. For example, tall buildings need to remain secure in high winds.

electrical engineer
an engineer who designs and organises electric circuits and equipment

civil engineer
an engineer who plans and designs structures

Check your learning 5.2

Recall and explain

1 Draw flow diagrams for the energy transformation process that happens in your house for:
   - **a** heating during winter
   - **b** cooling during summer.

2 **Explain** how an architect uses their knowledge of energy efficiency.

3 **Recall** how window awnings and verandas keep a house cool in summer.

4 **Define** the term 'engineering' in your own words.

Apply and analyse

5 Study Figure 3, which shows how much energy is used by different household appliances.
   - **a** **Identify** the appliance that uses the most energy.
   - **b** The clothes dryer uses more energy than the electric blanket. Use energy transformations to **explain** why.
   - **c** Many people switch their appliances off at the wall rather than use the standby function (where the television is still on but the screen is dark). Use energy efficiency to **explain** a possible reason for this.

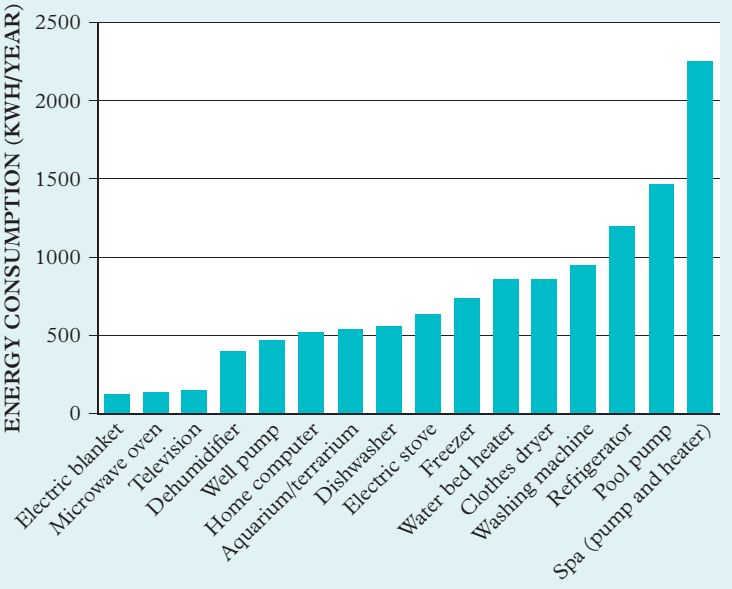


Figure 3 Energy used by different household appliances

Evaluate and create

6 **Discuss** how developments in technology help to minimise the amount of wasted energy.

Skills builder: Processing and analysing data

7 The temperature inside and outside a house was measured over four days and displayed in Figure 4.
   - **a** **Describe** the temperature in the house compared with the temperature outside. (THINK: What do you notice happening to the line representing the temperature of the house?)
   - **b** From the graph, **deduce** if the house was insulated. (THINK: Use the data as evidence to support your answer.)

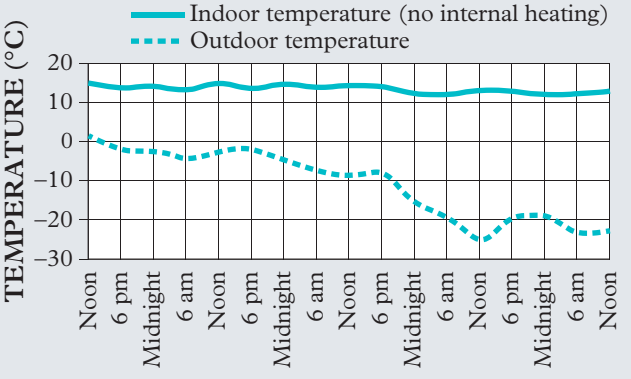


Figure 4 Temperature inside and outside house

5.3 Electrical energy can be generated efficiently

In this topic you will learn that:

- solar cells transform the Sun's light energy into electrical energy
- wind turbines transform the wind's kinetic energy into electrical energy.

Video
Ask a scientist – Dr Niraj Lal (Physicist)

photovoltaic cell (PVC) an electrical device that converts light energy into electrical energy; see solar cell

Energy efficiency is an important way for us to reduce our impact on the environment, but it is not the full story.

Even if we use a more energy efficient fridge at home, we are still relying on non-renewable resources, such as coal, to power it. To reduce our impact on the environment, we also need to use more efficient sources of energy.

Using solar energy in Australia

Australia is often known as the sunburnt country. This is a reference to the large number of hours each day that the Sun shines. Australia is a big country, and the number of hours of sunlight varies greatly depending on the location and the time of year.

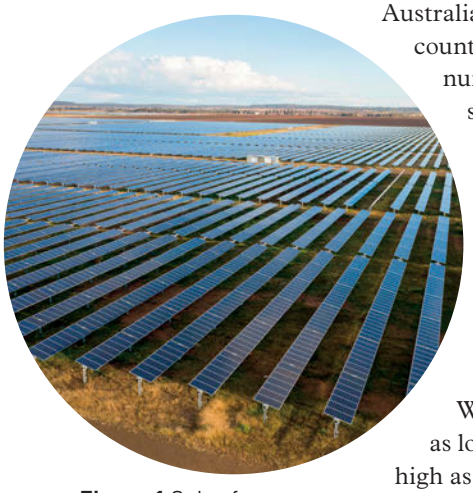


Figure 1 Solar farms convert sunlight into electricity on a large scale.

Solar energy is often measured in the number of peak sunlight hours every day. This is then averaged out over the whole year. For example, in the Hunter Valley in New South Wales, the number of peak hours can be as low as 4.0 hours per day in winter and as high as 6.5 hours per day in summer. Over a year this averages out to 5.6 hours each day. In Tasmania, the average number of peak hours is 3 hours per day. In Queensland, Northern Territory and Western Australia, the average number of peak hours each day is 6.

Converting light energy into chemical potential energy

Using light energy to power a house has its problems. The most common time people use electrical energy (at night) is not during the time that the light energy is available (daytime). This means the light energy often needs to be stored so that it can be used at night. The light energy is transformed into chemical potential energy in a battery so that it can be used to heat water, provide light or make energy for cooking.

Capturing the light energy

Solar panels are a collection of solar cells called **photovoltaic cells (PVCs)**. When light shines on the surface of these PVCs, the light energy is transformed into electrical energy. The most efficient PVCs currently convert 30 per cent of the energy they receive from the Sun.

Solar panels can be placed on rooftops to power homes and buildings. In Australia, over 21 per cent of homes have installed some kind of solar panels to convert sunlight into electricity. Solar panels can also be used on a larger scale, such as on solar farms (see Figure 1), to collect more energy.

Solar panels are still being investigated by scientists and engineers to work out how to make them more efficient (see Table 1).

Table 1 Making solar panels more efficient

Solar panel	Description	Efficiency (% of solar energy converted into useable electricity)
Monocrystalline	Most expensive to produce and buy, but the most energy-efficient solar panels on the market	15–21
Polycrystalline	More affordable than monocrystalline solar panels, but less efficient	13–16
Thin film	Very cheap to produce, but not very efficient; therefore, most suited to properties that have a lot of room to place more panels	11–13

INVESTIGATION
5.3: What time of day does the Sun produce the most energy? Go to page **363**.

Solar cars

Most solar-powered vehicles only carry one person. They are lightweight (approximately 600 kilograms), so they are more energy efficient. Although using a solar car for everyday travel is not currently practical, with more research it may be in the future.



Figure 2 Solar cars use solar energy to power their engines.

Wind turbines

Wind power is another renewable energy source, meaning it is naturally replenished. Like solar power, it is considered cleaner than other sources of energy, such as burning coal, because it creates no pollution.

Wind power is becoming more popular every year. In 2018, wind power made up just over 7 per cent of Australia's electricity and there are more wind farms under construction.

In the production of wind power, there is no chemical or heat energy required. The wind turbines capture the kinetic energy of the wind in their blades. The spinning blades power a generator that produces electricity.

Advances in wind power science are increasing the cost-effectiveness of wind power. Wind turbine design has improved, meaning fewer turbines are needed to produce the same amount of energy. Wind power is now the cheapest source of large-scale renewable energy.



Figure 3 Wind turbines in South Australia

Check your learning 5.3

Recall and explain

1 **Explain** what solar energy is.
2 What is a solar cell? **Recall** its other name.
3 **Outline** two advantages of using wind power.

Apply and analyse

4 **Explain** why it is important for the environment to use energy more efficiently.
5 **Assess** the advantages solar cars may have over petrol cars.
6 Using the information in Table 1, **recommend** a solar panel for each of the following people.
   a Jane lives on a large farm and would like a solar panel to power her home, but she is not sure if she has the money to afford it.
   b Jay lives in the city and would like the most efficient solar panel that money can buy.

Skills builder: Questioning and predicting

7 Consider the following question: 'Is solar power better than wind power?'
   a **Identify** three ways this question could be improved. (THINK: Is this question testable, specific or based on opinion?)
   b **Propose** a new question based on your suggestions.

REVIEW

Multiple choice

1 Which of the following is true about energy?
- **A** Energy cannot be created or destroyed.
- **B** Energy is destroyed once it has been used.
- **C** Energy is created constantly.
- **D** Energy is precious because it is difficult to find.

2 Why are incandescent light bulbs not as efficient as CFLs or LEDs?
- **A** Incandescent bulbs take longer to manufacture.
- **B** Incandescent bulbs waste energy by producing more heat.
- **C** Incandescent bulbs are a lot more expensive.
- **D** Incandescent bulbs are harder to install.

3 How can insulation help to make a house more energy efficient in summer?
- **A** It captures light energy to power the house.
- **B** It stops heat getting in through the windows.
- **C** It deflects light energy away from the house.
- **D** It helps to keep heat out of the house during the day.

Recall and explain

4 **Recall** the formula to calculate energy efficiency.

5 Are the following statements true or false? For false statements, rewrite them to make them true statements.
- **a** Some appliances are 110 per cent efficient.
- **b** Energy cannot be created but can be destroyed.
- **c** Incandescent lamps are the least efficient type of light bulbs.

6 **Explain** why it was not cost effective to transmit electricity to remote areas before the invention of transformers.

7 **Outline** the law of conservation of energy using your own example.

Apply and analyse

8 A refrigerator cools the food inside it.
- **a** **Explain** how a refrigerator does this.
- **b** **Describe** possible energy transformations that may occur in a refrigerator

9 **a** **Calculate** the percentage efficiency of a device if it transforms:
- **i** 30 units of input energy into 15 units of useful output energy
- **ii** 600 units of input energy into 500 units of useful output energy.

b For part (a) above, where did the other energy go – that is 8 units in (i) and 100 units in (ii)?

10 **Propose** a reason why 6-star energy-rated appliances are rare.

11 Choose at least 5 appliances at your home.
- **a** Determine their energy transformations. What kind of useful or wasted energy do they produce? For example, in an electric heater, electrical energy transforms to heat, light and sound energy. Heat energy is useful, sound and light energies are waste energy.
- **b** Tabulate your results.

12 Solar panels and wind turbines may one day replace coal-fired power stations. Which form of energy would you prefer to supply your power and why?

13 The table below shows the data about different imaginary brands of the same size refrigerators.

Brand's name	Input energy (J)	Useful output energy (J)	Wasted energy (J)	Efficiency (%)
Glacier	200	100	100	
Ice	180	100	80	
Avalanche	150	100	50	
Frozen	130	100	30	

- **a** **Calculate** energy efficiency to fill in the above table.
- **b** **Construct** an appropriate graph to compare the efficiency of the different brands.
- **c** **Identify** which fridge is more cost effective and environmentally friendly. **Account** for your answer.

14 Jada was deciding which types of lights to use in her new house. She wanted to find the lights that would last the longest.
- **a** **Compare** the different ratings for each type of light in Figure 2.
- **b** Write a recommendation for Jada that uses the information in Figure 2 to explain which type of light she should use.

Evaluate and create

15 A friend of yours is considering buying a 2-star energy-rated device because it is slightly cheaper than a 4-star device. **Outline** the advice you might give your friend.

16 **Identify** the by-product energy transformations for a car.

17 **Discuss** how a house can be designed to make it more energy efficient.

18 'The sun rises in the east and sets in the west.' **Discuss** how this information might influence the orientation of an energy-efficient house and where its windows are placed.

19 Using your discussion from questions 17 and 18, **construct** a diagram to show the design of an energy-efficient home. Label each of the features that make it energy efficient.

Critical thinking

20 **Consider** your energy usage at home. Do you waste energy? **Propose** three ways that you might make your energy use at home more efficient.

21 Think about the energy transformations involved in sliding down a water slide.

- **a** **Identify** the energy transformations taking place when someone goes down a water slide.
- **b** What might slow a person down as they go down the water slide? **Propose** a way this could be reduced to make the slide more energy efficient.

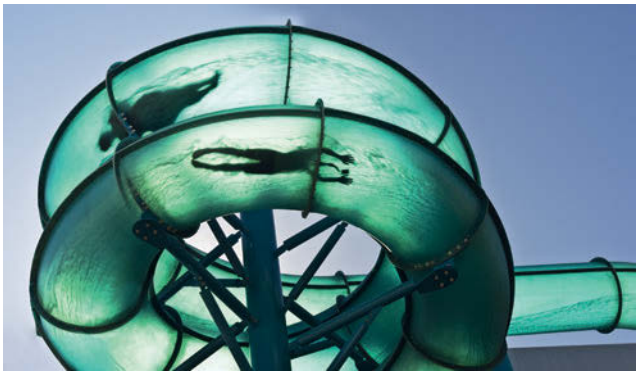


Figure 1 Water slides transform the gravitational potential energy of the water into kinetic energy.



Figure 3 Verandas and window awnings can limit heat transfer.

Going further

22 'The more efficient a light bulb, the more environmentally friendly and cost effective it will be.' **Discuss** this statement.

23 Design an experiment to compare the efficiency of two different light bulb brands.

- **a** Write a scientific question for this investigation.
- **b** Determine dependent, independent and at least two controlled variables.
- **c** Write a step-by-step method.
- **d** Create a risk assessment for this experiment.

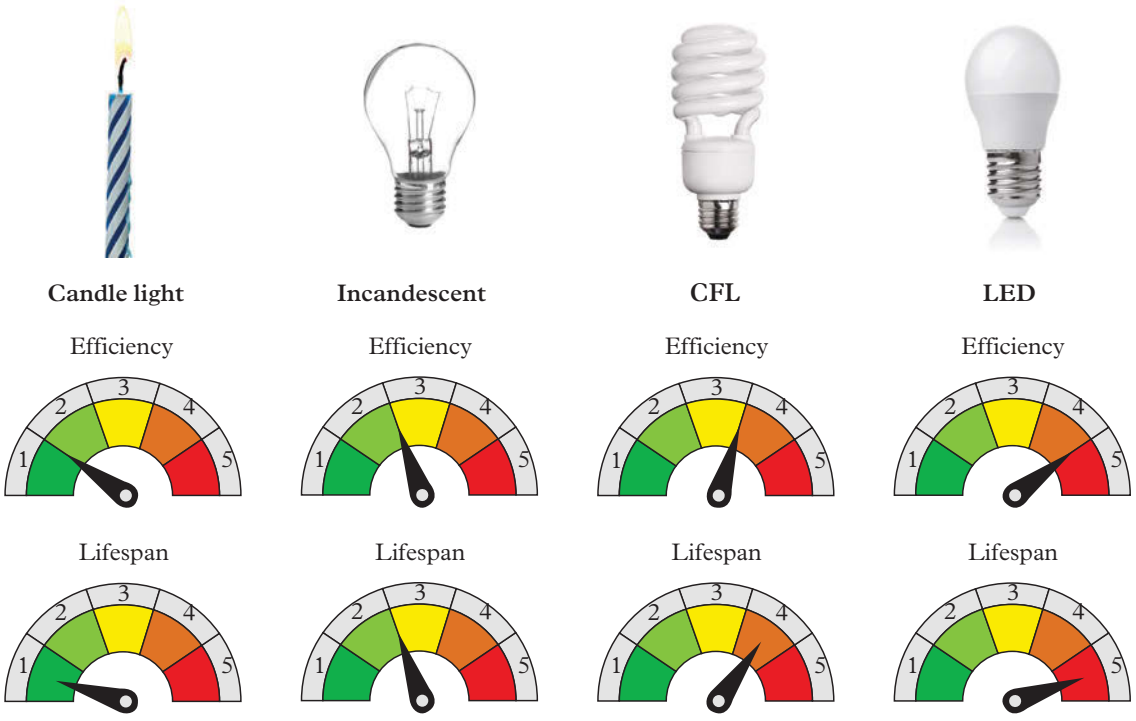


Figure 2 Different types of light bulbs

Research

24 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions than you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

» Energy-efficient housing

In previous societies, energy efficiency was important because people had limited access to the types of energy supplies and their applications that we have today. Research how civilisations in tropical areas designed their homes to keep them cool and damp free. What types of energy-efficient practices have humans used through the ages?

» Compact fluorescent lights

How do compact fluorescent lights (CFLs) work? How do they differ from fluorescent light globes? Why are CFLs initially more expensive to buy but then more economical over time? What is the benefit of using CFLs?

» Star ratings

Investigate the star rating system for indicating the energy efficiency of appliances. **Identify** how the star rating for an appliance is determined. How could these ratings be useful for the general public?

» The Magenn Air Rotor System

Originally designed for generating electricity in remote areas, the Magenn Air Rotor System (MARS) is another way to harness wind energy. **Investigate** this new technology. How does it work? How do you think it compares with a more traditional wind turbine?



Figure 4 Compact fluorescent lights

Reflect

Now that you've completed this chapter, reflect on your ability to do the following:

	I can do this.	I can't do this yet.
Identify that most energy conversions are inefficient and lead to the production of heat energy, e.g. in light bulbs.	☐	☐ Go to page 76–77.
Research ways in which scientific knowledge and technological developments have led to finding a solution to contemporary issues, e.g. improvements in devices to increase the efficiency of energy transfers or conversions.	☐	☐ Go to page 78–81.
Discuss the implications for society and the environment of some solutions to increase the efficiency of energy conversions by reducing the production of heat energy.	☐	☐ Go to page 80–81.

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THE CHANGING EARTH

What is the Earth made of?



Have you ever wondered ...

- How long is the journey to the centre of the Earth?
- Where does sand come from?
- Why are fossils found in rocks?

6

SCIENCE UNDERSTANDING

In this chapter you will learn how to:

- describe the structure of the Earth in terms of core, mantle, crust and lithosphere
- relate the formation of a range of landforms to physical and chemical weathering, erosion and deposition
- outline the origins of and relationships between sedimentary, igneous and metamorphic rocks
- identify that sedimentary, igneous and metamorphic rocks contain minerals
- classify a variety of common rocks and minerals into groups according to their observable properties
- describe the conditions under which fossils form
- outline how geological history can be interpreted in a sequence of horizontal sedimentary layers, in which the oldest are at the base and the youngest at the top
- describe examples to show how people use understanding and skills from across the disciplines of science in occupations related to the exploration, mining or processing of minerals in Australia.

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Check your Student obook assess for these digital resources and more:

QuizletLive
Compete in teams to test your knowledge.

Assess quiz
Before you start this chapter, assess your science skills.

Check your Teacher obook assess for these digital resources and more:

QuizletLive
Launch a quiz for your students on key concepts in this chapter.

6.1 The Earth is made of layers

In this topic you will learn that:

- the Earth is made up of layers, including the core, mantle and crust
- the lithosphere is the rigid, rocky layer that includes the crust and the uppermost part of the mantle.

lithosphere
the rocky outer layer of the Earth's surface that is made up of the crust and uppermost part of the mantle

layer
the property of rocks used to identify them

tectonic plate
a massive slab of rock that forms part of the lithosphere

magma
hot, molten rock beneath the Earth's surface

mantle
the part of the Earth between the crust and the outer core

crust
the outer layer of the Earth

What is the Earth made of?

Although the Earth can be described as a solid planet, it began as a ball of molten materials. Scientists believe the Earth and other planets are the result of an explosion billions of years ago. According to this theory, the Earth began as a molten fragment from this explosion. As it hurtled through space, the outside **layers** cooled, forming a ball of solid rock and ice.

The Earth's surface has continued to slowly change and is still changing – many rocks have worn down to form soil and sand, mountains and valleys have formed, and the land and oceans have changed shape. Some of this change is caused by erosion and weathering at the surface. It is also due to the movement of the molten rocks from deeper down, which in places push their way up to the surface and also move sections of the Earth's crust.

If you could journey deep inside the Earth, you would find that it is made of several layers.

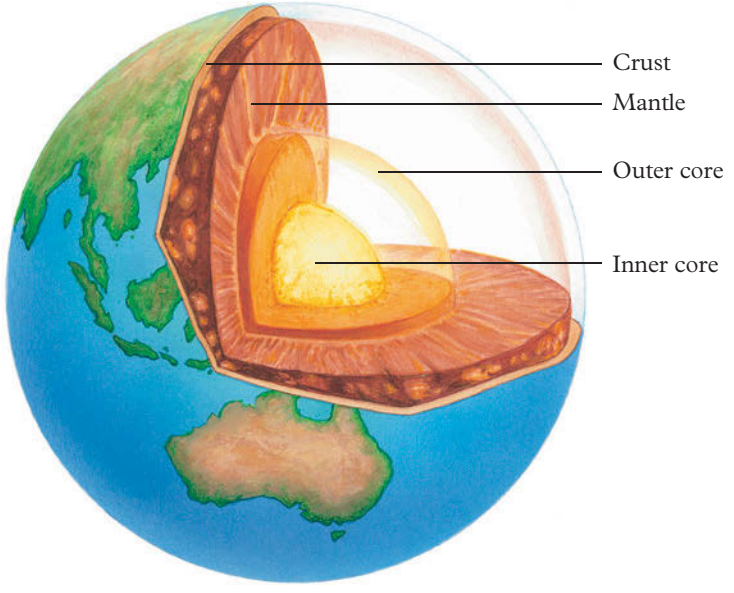


Figure 1 Layers of the Earth

Core

The core is the centre of the Earth. It consists of the outer core and the inner core. The outer core is made mainly of metals, not rock; the main metal is iron, possibly with some nickel. It is very hot and liquid, with temperatures ranging from 4000°C to 6000°C. The heat comes from nuclear reactions, and some of the heat is left over from when the Earth was formed. The outer core gives the Earth its north and south poles and magnetic field. The temperature of the inner core is almost 10 000°C. The inner core does not melt or boil because of the weight of the rest of the Earth pushing down on it. Of course, no geologist has ever seen the core. Even our deepest mines only penetrate a few kilometres of the Earth's crust.

Mantle

The **mantle** is below the crust. It is about 2800 kilometres thick. Temperatures near the crust are about 500°C; at the bottom of the mantle, they reach 3000°C. Although the bottom of the mantle is solid, nearer the top the rock slowly moves due to convection currents. The upper mantle is more like modelling clay than solid rock. It is the source of volcanoes and earthquakes. The lower mantle is made up of more solid rock.

Crust

The **crust** is the outer layer (7–50 kilometres thick) of the Earth. It is made up of rocks and minerals, and a lot of it is covered by water. The Earth's crust is the thin outer coating of the planet, like the shell on an egg. The Earth's surface is not smooth. It has hills, mountains, valleys, oceans and deserts. In fact, 70 per cent of the crust is covered by oceans. The crust is thickest under the continents and thinnest under the oceans. Compared with the rest of the Earth's layers, the crust is very thin and brittle.

CHALLENGE
6.1: Identifying rocks
Go to page **364**.

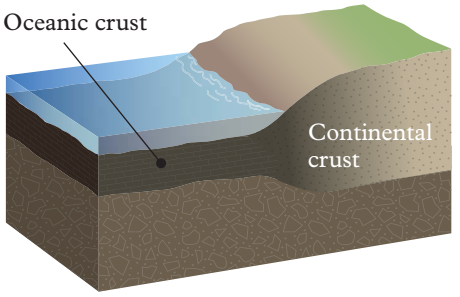


Figure 2 The oceanic crust is thinner beneath the ocean than it is beneath the continents.

The lithosphere

The **lithosphere** is made up of the Earth's crust and the top part of the upper mantle. It is the rigid, rocky outer layer of the Earth.

The lithosphere is broken into a number of pieces called **tectonic plates**. These plates float on the semiliquid **magma** in the upper mantle. This zone just below the lithosphere is known as the asthenosphere.

The speed of tectonic plate movement is similar to fingernail growth: between 1 centimetre and 10 centimetres per year. Sometimes the tectonic plates crash into one other, causing one plate to slide under another. The plate on top buckles under pressure, pushing the land upwards. For example, the Indo–Australian Plate is sinking under the Eurasian Plate. This has caused the Eurasian Plate to buckle, pushing up the world's highest mountain range – the Himalayas.

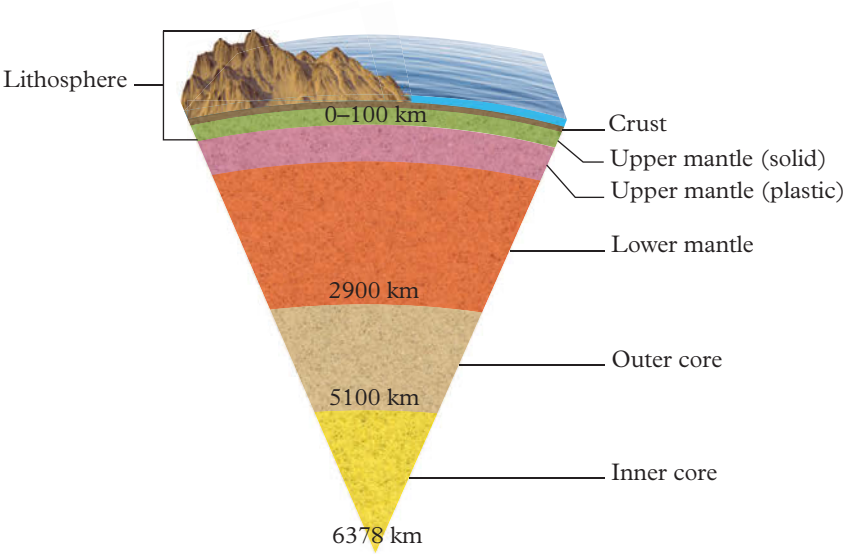


Figure 3 The lithosphere is the rigid outer layer of the Earth.

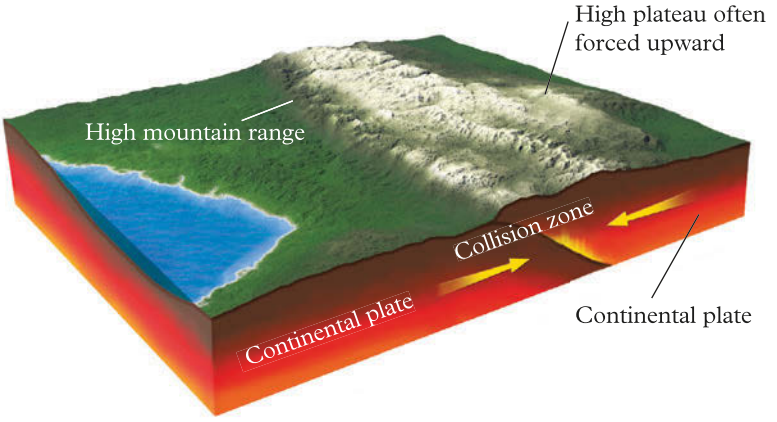


Figure 4 Colliding plates cause the Earth to buckle.

Check your learning 6.1

Recall and explain

1 **Describe** the structure of the Earth in terms of crust, mantle and core.
2 **Describe** the structure of the lithosphere.
3 **Recall** in which layer of the Earth tectonic plates are found.

Apply and analyse

4 **Distinguish** between the Earth's crust and the lithosphere.
5 If the Earth has a radius of about 6370 kilometres, use the information about the crust and the mantle to **calculate** the thickness of the Earth's core.

Evaluate and create

6 'The Earth's crust is the same thickness everywhere.' **Discuss** why you agree or disagree with this statement.

Skills builder: Questioning and predicting

7 A team of scientists were trying to drill the deepest hole in the world. They planned to dig 20 kilometres down.

a **Predict** what the ground will be like to dig at about 15 kilometres down. (THINK: What layer of the Earth will they reach?)

b **Explain** how you made this prediction. (THINK: What scientific knowledge did you use?)

6.2 Rocks have different properties

In this topic, you will learn that:

- rocks can be classified using their observable properties.

property
a characteristic of a rock

geologist
a scientist who studies rocks

crystal
a small, organised particle in rocks that has smooth sides and sharp edges

grain
a small rock particle; grain size can be used to identify rock type

Rocks don't all look and feel the same. Each rock has characteristics that give clues to its identity, such as its colour or hardness. These characteristics are referred to as **properties**. By making careful observations of a rock's properties, **geologists** can tell where a rock came from and what has happened to it.

Identifying and selecting rocks

We select rocks for particular purposes because of their properties. For example, granite is selected for kitchen benchtops because it is the hardest building stone, not porous (does not let liquid through), not affected by temperature and resistant to damage from chemicals.

You can identify rocks first by how they look. Coal is black or dark brown. Pumice and scoria are covered with holes. Conglomerates are made up of individual stones cemented together. Granite is made up of large **crystals** of the minerals quartz, mica and feldspar.

Geologists also use a range of other properties to help identify rocks, such as colour, layering, weight and the presence of crystals or **grains**.

Table 1 lists some different types of rocks and how they can be identified.



Figure 2 Marble

Table 1 Rock identification

Rock	Grain size	Hardness	Usual colour	Density
Basalt	Fine or mixed	–	Dark	2.8–3
Coal	Fine	Soft	Dark	1.3
Conglomerate	Mixed	Hard or soft	–	–
Gneiss	Coarse	Hard	Alternating light and dark bands	2.6–2.3
Granite	Coarse	Hard	Light	2.6–2.7
Limestone	Fine	Soft	Light	2.3–2.7
Marble	Coarse	Soft	Light	2.4–2.7
Obsidian	Fine	Soft	Dark	2.6
Pumice	Fine	–	Light	0.6
Quartzite	Coarse	Hard	Light	2.6–2.8
Rhyolite	Fine	Hard	Light	2.4–2.6
Sandstone	Coarse	Hard	Light	2.2–2.8
Schist	Medium to coarse	Medium	Medium	2.5–2.9
Scoria	Fine	–	Dark	0.9
Shale	Fine	Soft	–	2.4–2.8
Slate	Fine	Soft	Dark	2.7–2.8



Figure 1 Conglomerate

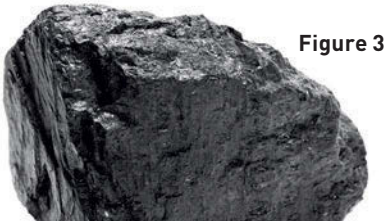


Figure 3 Coal



Figure 4 Colour in rocks
Colour is a property that depends on the chemicals in rocks. For example, some red rocks contain a lot of iron, which has reacted with oxygen in the air ('rusted') to form red iron oxide. Other red rocks don't contain iron, so a rock cannot be identified solely by its colour.



Figure 5 Layers in rocks
Layers in rocks can look very different. Some rocks have different-coloured layers that line up like ribbons. Gneiss usually has alternating layers of colours, often black and white. Sandstone has layers of different-sized grains of sand. Wind or water distributes the sand so that the rock ends up being different shades of the same colour.



Figure 6 Gas holes in rocks
Some rocks contain large gas holes that are produced when the rock is formed. This reduces their density and weight. In pumice, the holes can be the size of a matchhead or smaller. In scoria, the holes are often the size of a pea.



Figure 7 Crystals in rocks
Crystals are small pieces of organised particles that have smooth sides and sharp edges. They are usually just one colour and often reflect light off their flat surfaces. Crystals in a rock can be different sizes.



Figure 8 Grains in rocks
Grains are small pieces of material that can be rounded or jagged. The size of the grain can be used to identify the type of rock. Large grains (the size of a grain of rice or larger) are said to be coarse. Grains that are smaller, but which can still be seen with the eye, are considered medium grained. Fine grains cannot be seen without a microscope.



Figure 9 Gneiss



Figure 10 Limestone

Check your learning 6.2

Recall and explain

1 **Explain** how physical properties are used to identify different types of rocks. Use examples to illustrate your answer.

2 **Explain** how the properties of granite make it useful.

Apply and analyse

3 Use Table 1 and Figures 1–9 to **classify** the following rocks.

- **a** I am soft with distinctive layers.
- **b** I am light in colour with holes in my surface.
- **c** I am soft, shiny and used for flooring.
- **d** I am white with coarse grains and am used for sculptures.

4 **Deduce** why properties other than colour must be used to identify a rock.

5 Pumice has a density of 0.6. Water has a density of 1. **Predict** whether you think pumice stone would float or sink in water. **Explain** your reasoning.

Skills builder: Planning investigations

6 James was conducting an investigation about the properties of different rocks. He collected a piece of coal, pumice, sandstone and scoria. He then placed them in a large bucket of water and observed which floated and which sunk. Write an aim for James' investigation. (THINK: What property was he trying to observe? Can you identify the independent and dependent variables in this investigation?)

6.3 Rocks are made up of minerals

In this topic you will learn that:

- rocks are made up of one or more types of minerals
- the physical properties of rocks can be used to identify minerals correctly.

mineral
a naturally occurring solid substance with its own chemical composition, structure and properties

Rocks are made up of one or more minerals. A **mineral** is a naturally occurring solid substance with its own chemical composition, structure and properties. There are more than 4000 minerals known, but only approximately 150 of these are common.

Properties of minerals

Minerals are found as crystals (see Figure 1). The structure of a crystal greatly influences a mineral's properties. For example, diamond and graphite have the same chemical composition – they are both pure carbon. Graphite (which is the 'lead' in a pencil) is very soft, whereas diamond is the hardest of all minerals. This difference arises because the carbon particles in a graphite crystal are arranged into sheets that can slide past each other, whereas the carbon particles in a diamond crystal form a strong, interlocking unit (see Figure 2).

Interactive
Classifying rocks

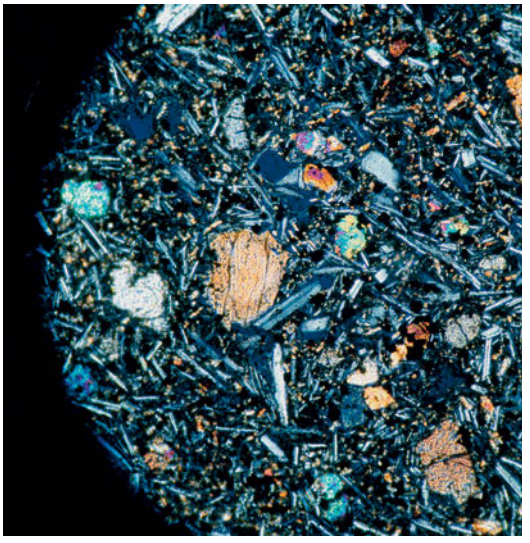


Figure 1 The individual mineral crystals of the rock olivine basalt viewed under a microscope

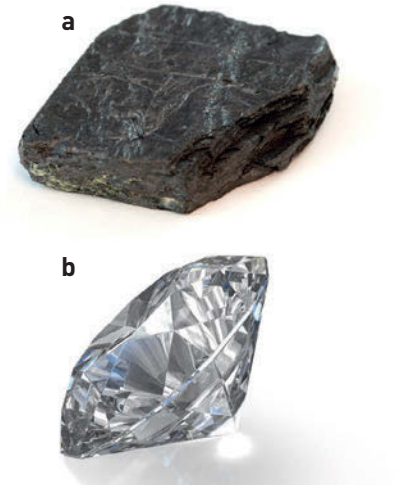


Figure 2 a The carbon atoms in the mineral graphite are arranged in sheets. **b** In a diamond, the carbon atoms are interlocked.

Identifying minerals

To identify minerals correctly, geologists carefully examine the properties of rocks.

The colour of a mineral is a guide to identifying it, but it cannot be relied on for correct identification. Colour is not a reliable property because many minerals are impure. For example, pure quartz is colourless; however, if it contains impurities, it can be many colours, such as purple (amethyst), pink (rose quartz) or yellow (citrine). Even in one sample, the colour may vary.

lustre
the shininess of the surface of a mineral

Lustre is the shininess of the surface of the mineral (see Figure 3). Some types of lustre are:

- metallic – looks like a shiny new coin
- brilliant – very shiny, like a mirror
- pearly – a bit shiny, like a pearl or fingernail
- dull – not shiny at all
- earthy – looks like a lump of dirt.

SKILLS LAB
6.3: Testing the hardness of common substances
Go to your obook.

INVESTIGATION
6.3: What affects crystal size?
Go to page **365**.



Figure 3 The lustre of a mineral describes its shininess.

Streak is the colour of the powdered or crushed mineral. This colour can be seen by drawing with the mineral on a footpath. The colour of the line that the mineral leaves behind is its streak. Often the colour of the streak is different from the main colour of the mineral.

Hardness is how easily a mineral can be scratched. Some minerals are so soft that they can be scratched with a fingernail. Other minerals are so hard that they can scratch glass. A hard mineral can scratch a soft mineral and not get scratched itself. German geologist Friedrich Mohs (1773–1839) invented a scale to describe the hardness of a mineral. Mohs gave a hardness number to ten common minerals (see Table 1): the softest mineral, talc, has a hardness of 1; the hardest mineral, diamond, has a hardness of 10. These minerals can be used to find the hardness of any other mineral.

A mineral will scratch another mineral with a lower hardness number but not one with a higher hardness number. A mineral will be scratched by another mineral with a higher hardness number but not one with a lower hardness number. So, copper (hardness 3.5) will be scratched by fluorite (hardness 4), but not by calcite (hardness 3). Copper will scratch calcite. Fingernails have a hardness number of 2.5; iron nails and glass microscope slides have a hardness number of 6.5.

Table 1 The Mohs scale of mineral hardness – every mineral will scratch the minerals above it.

Hardness	Mineral
1	Talc
2	Gypsum
3	Calcite
4	Fluorite
5	Apatite
6	Feldspar
7	Quartz
8	Topaz
9	Corundum
10	Diamond

Cleavage is the tendency of a mineral to break into a number of smooth flat surfaces. Minerals that demonstrate cleavage look like thin slabs stuck together. For example, mica breaks in one direction into flat layers, like the pages in a pile of papers. Calcite breaks along three cleavage planes: left and right, front and back, and top and bottom.

Several minerals have unusual properties. Some minerals fluoresce in ultraviolet (UV) light: these minerals absorb UV light, which we cannot see, and emit it as visible light, which we can see. Calcite is a transparent mineral. When you look through it, you see a double image.



Figure 4 Mica has one cleavage plane – it breaks into thin sheets of rock.

streak
the colour of powdered or crushed mineral

hardness
how easily a mineral can be scratched; measured on the Mohs hardness scale

cleavage
a number of smooth planes that a mineral breaks along



Figure 5 Calcite is a transparent mineral.

Check your learning 6.3

Recall and explain

1 **Identify** a mineral that has a Mohs hardness of 10.

2 **Describe:**
- **a** hardness
- **b** lustre
- **c** streak
- **d** cleavage.

3 **Explain** what it means if a mineral has a hardness of 1 on the Mohs scale.

4 **Describe** the lustre of gold.

Skills builder: Conducting investigations

5 Stephen and Anita were asked to observe a piece of calcite and take notes about its cleavage, hardness and streak.

- **a** **Identify** two potential hazards that Stephen and Anita should be careful of during their investigation. (THINK: What do we know about calcite? How could it be dangerous?)
- **b** For the two hazards you identified, recommend a strategy to reduce the risk of each. (THINK: Could they change the way they behave or the equipment they use to make the investigation safer?)

6.4 Igneous rocks develop from magma and lava

In this topic you will learn that:

- igneous rocks are formed when magma and lava cools and solidifies
- extrusive igneous rocks form on the surface of the Earth, while intrusive igneous rocks form slowly beneath the surface.

intrusive igneous rock
rock formed underground by slowly cooling magma

lava
hot, molten rock that comes to the surface of the Earth in a volcanic eruption

igneous rock
rock formed by cooling magma and lava

extrusive igneous rock
rock formed at the Earth's surface by quickly cooling lava

Rocks are broadly classified according to how they are formed. The three main types of rocks – igneous, sedimentary and metamorphic – form in different ways.

Magma and lava

The term 'igneous' comes from the Latin word *ignis*, which means 'fire'. The hot, molten rock inside the Earth is called magma and its temperature can be more than 1200°C. The magma chamber under a volcano is the source of molten rock for volcanos (see Figure 1).

In a volcanic eruption, the red-hot magma rushes out onto the surface of the Earth as **lava**. The cooler conditions at the Earth's surface help to solidify the lava quickly. **Igneous rocks** also form from magma under the ground. These igneous rocks look quite different from those formed on the Earth's surface because they cool much more slowly.

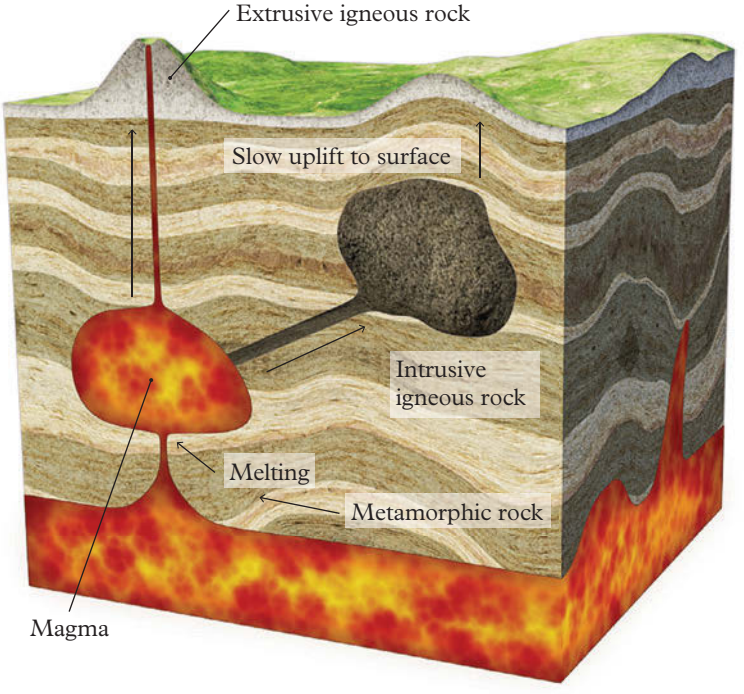


Figure 1 Igneous rocks are formed from volcanic magma.

Intrusive igneous rocks

Intrusive igneous rocks form slowly beneath the surface of the Earth when magma becomes trapped in small pockets. These pockets of magma cool slowly underground (sometimes for millions of years) to form igneous rocks. The longer it takes for lava to cool, the bigger the rock crystals that grow. Intrusive igneous rocks have large crystals locked together. Granite is an intrusive igneous rock in which the crystals can be seen with the naked eye (see Figure 2). Although formed underground, intrusive igneous rocks reach the Earth's surface when they are either pushed up by forces in the Earth's crust or uncovered by erosion.

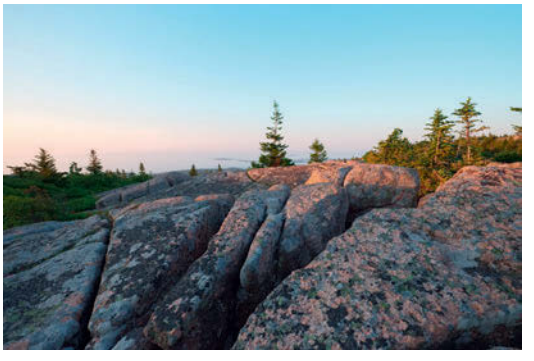


Figure 2 Granite is an intrusive igneous rock.

Extrusive igneous rocks

Lava cools much more quickly on the surface of the Earth. This causes it to form **extrusive igneous rock**. Because the lava is cooling much more quickly than the magma underground, the crystals that are formed are small. Sometimes, the lava cools so quickly that no crystals are

formed. For example, pumice has no crystal structure. It forms when hot, gas-filled lava cools very quickly. The many tiny holes in pumice are formed by volcanic gases escaping from the cooling lava (see Figure 3). It has so many holes that it is extremely light and can float on water. Pumice stones are used to scour hard skin from feet, and powdered pumice is found in some abrasive cleaning products.



Figure 3 Pumice contains many holes, which make it light enough to float on water.

The different forms of basalt

Magma can solidify into different igneous rocks, and the same type of rock can have different appearances. This is because of how igneous rocks form and what they are made of.

Basalt is the most common type of rock in the Earth's crust. Most of the crystals in basalt are microscopic or non-existent because the lava cools so quickly that large crystals do not form.

We commonly think of basalt as the building product bluestone. However, basalt can look different depending on the type of volcanic eruption that produced it and how quickly it cooled.

Scoria is a type of basalt that is full of bubble holes. The lava was filled with gases when it began to cool and the holes in the scoria are where the gas bubbles once were. Scoria is a light rock that is often used for garden paths and as fill-in drainage trenches.

Obsidian is a smooth, black rock that looks like glass. It is formed when lava cools almost instantly and forms no crystals. Obsidian is used to make blades for surgery scalpels; the resulting blades are much sharper than those made from steel.



Figure 4 Basalt comes in different forms: **a** bluestone, **b** scoria and **c** obsidian.

Check your learning 6.4

Recall and explain

1 **Define** the term 'igneous'.
2 **Describe** how igneous rocks form.
3 **Identify** the type of rock that is produced by magma that cools deep below the Earth's crust.
4 **Identify** an igneous rock that is able to float on water.

Evaluate and create

5 The ancient civilisations that discovered obsidian had a competitive advantage over those who didn't. **Discuss**.

Skills builder: Processing and analysing information

6 In this topic we have learnt about different types of igneous rocks, including pumice, obsidian, scoria and basalt. **Construct** a table to clearly organise the information found in this topic about the properties of pumice, obsidian, scoria and basalt. (THINK: What information do you have and how can you group it?) Remember that a table should always have a heading and that columns should have labels.

6.5 Metamorphic rocks require heat and pressure

In this topic you will learn that:

- metamorphic rocks are formed by heat and pressure inside the Earth in a process called metamorphism
- metamorphism can cause chemical and physical change.

metamorphic rock
rock formed from other rock that has experienced intense heat and pressure

foliation
layering in metamorphic rocks produced under uneven, high pressure

Metamorphic rocks are formed when other types of rocks are changed by incredible heat and pressure inside the Earth. When igneous, sedimentary or even metamorphic rocks are heated to extreme temperatures by magma, or when they are placed under extreme pressure from the layers of rocks above them, they can change into different types of rocks.

Change in appearance

The combination of high temperatures and pressures causes differences in the appearances of metamorphic rocks. (Metamorphism means 'change in form'.) As you go deep underground, the temperature gradually increases. Miners in the West Wits minefield in South Africa, who work up to 3.9 kilometres below ground, report temperatures as high as 60°C. Temperatures can get much higher anywhere magma intrudes.

The pressure of the earth above the rock also contributes to the different appearances of metamorphic rocks. Bands can occasionally be seen in metamorphic rocks formed under high pressure. This is called **foliation**. Sometimes the pressure is uneven, causing the rock crystals to twist.

Change in the minerals

Metamorphic rocks also change chemically. Some metamorphic minerals, such as sillimanite, kyanite and garnet, only form at high temperatures and pressures. They are called **index minerals** because they can tell us the history of what happened to the mineral – the temperature and pressure it was exposed to. Other minerals, such as quartz, can withstand high temperatures and pressures and can sometimes be found in metamorphic rocks. The heat and temperature can cause some crystals to change their size and shape.

index mineral
a mineral that only forms under a particular temperature and pressure; used to determine the history of the mineral



Figure 1 Foliation occurs when rock is subjected to uneven pressure.

SKILLS LAB
6.5: Making a metamorphic rock
Go to page **366**.

Recrystallisation occurs when the crystals are squeezed together so tightly that they partially melt and form fewer, but larger, crystals. For example, when granite is squeezed under high pressure, the crystals change and the rock gneiss is formed (see Figure 2).



Figure 2 When granite **a** is subjected to high heat or pressure, it can change into the metamorphic rock known as gneiss. **b** The bands on gneiss show that the crystals have been squeezed together under immense pressure.

Metamorphic rocks, such as slate and marble, are stronger than the original material because the particles have been fused together under great pressure or heat.



Figure 3 Slate cleaves easily into flat sheets because of its flat, parallel crystal structure. This makes it a useful material for floor and roof tiles and as the base for billiard tables.



Figure 4 The Taj Mahal in India is made of marble, the metamorphosed form of limestone. With its dense composition and beautiful patterns, marble is also a popular material for sculptures and kitchen benchtops.

Check your learning 6.5

Recall and explain

1 **Describe** how metamorphic rocks form.
2 **Identify** where metamorphic rocks form.
3 **Describe** a foliated rock.

Apply and analyse

4 A student claimed that a rock had to be igneous because it had quartz crystals. Are they correct? **Explain**.
5 Which type of rock is stronger: sandstone or marble? **Explain** your reasoning.

Skills builder: Problem solving

6 A builder was asked to choose between slate or pumice as a building material for the floor of a house.
   a **Identify** the advantages and disadvantages of using pumice and slate. (THINK: What are the properties of both materials? How would these properties impact on their function as a flooring material?)
   b **Identify** which option you think is best.

6.6 Sedimentary rocks are compacted sediments

Video
Sedimentary rocks

In this topic you will learn that:

- sedimentary rocks are formed when lose particles (sediment) are compacted by the pressure from overlying sediment.

sedimentary rock
rock formed from compacted mud, sand or pebbles, or the remains of living things



Figure 1 Shale (or mudstone) is the most common sedimentary rock. Shale is a fine-grained sedimentary rock made up of clay minerals or mud.

Sedimentary rocks are formed when loose particles are pressed together (or compacted) by the weight of the overlying sediments. Sediments are rock particles, such as mud, sand or pebbles, that are usually washed into rivers and eventually deposited on the riverbed or in the sea. Sediments can also come from the remains of living things, such as plants and animals.

Sediment

Over thousands or even millions of years, sediments form thick layers on the riverbed or sea floor (see Figure 3). Pressure from the overlying sediments and water squeezes out air and any gaps in the bottom layer. Over time, the compacted sediments become sedimentary rocks.

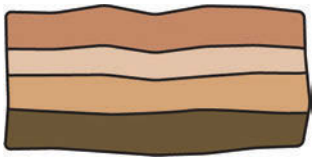
The names of some sedimentary rocks are clues to the sediments that formed them – mudstone, sandstone, siltstone and conglomerate are all types of sedimentary rock. Sandstone is made up of sand deposited in environments such as deserts and beaches. Conglomerate is a mixture of all sizes of rocks that have become cemented together.



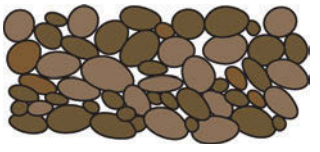
Figure 2 Conglomerate rocks have grains of different sizes. The sediments for these rocks were deposited in fast-flowing rivers during flooding or by glaciers.

Biological rocks

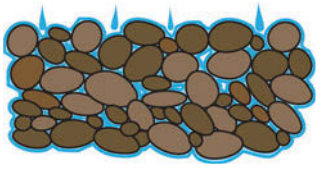
Sedimentary rocks are not always formed from the sediments of minerals or other rocks. The remains of living things also break down and are deposited as sediments. Shells and hard parts of sea organisms break down and are deposited in layers on the ocean floor. Eventually, they become cemented together under pressure to form limestone.



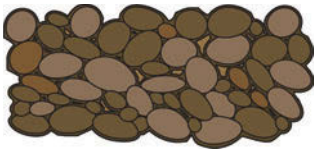
Sediments are deposited in layers called beds.



The grains of sediment in lower layers begin to squash together.



Chemicals that are dissolved in the water can soak into the sediments.



The chemicals help cement the grains together once the water has evaporated.

Figure 3 The formation of sedimentary rocks

The compaction of dead plant material can also help form sedimentary rocks. For example, coal is formed from dead plants that were buried before they had completely decayed (see Figure 5). Pressure from the layers above can change the plant material into coal or oil.

SKILLS LAB
6.6: Making sedimentary rocks
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Chemical rocks

Chemical sedimentary rocks form when water evaporates, leaving behind a solid substance. When seabeds or salt lakes, such as Lake Eyre in South Australia, dry up, they leave a solid layer of salt behind. If the layer of salt is compressed under the pressure of other sediments, it may eventually form rock salt.

Limestone caves

When groundwater passes over limestone, it can dissolve calcium carbonate from the limestone. When the water evaporates, it leaves behind the calcium carbonate. Various rock formations in caves are formed by this method.

The amazing long strands of rock found on cave floors and ceilings are composed of calcium carbonate from the limestone ceiling of the cave. A stalagmite grows from the floor towards the ceiling (they 'might' reach the ceiling one day), and a stalactite grows down from the ceiling (they hold on 'tight'). If these formations meet in the middle, they form a column.

Stalagmites and stalactites form when limestone rocks are dissolved by acids in water. The acid and dissolved limestone form a solution that drips through the ceiling of the cave and is deposited on the stalagmites and stalactites, gradually increasing their width and length.



Figure 4 Sandstone is a popular building material. This ancient temple of Abu Simbel in Egypt was carved directly into the sandstone rock.



Figure 5 Coal is formed from dead plant material.



Figure 6 Stalagmites and stalactites in a limestone cave

Check your learning 6.6

Recall and explain

1 **Describe** how sedimentary rocks form.
2 **Explain** how stalactites and stalagmites form.
3 **Outline** how chemical sedimentary rocks form.

Apply and analyse

4 A student claims that sandstone is made up of sand. Do you agree or disagree? **Explain**.
5 **Classify** the following rocks as conglomerate or not based on their visible physical properties.

a 
b 
c 

Skills builder: Communication

6 Imagine that you needed to explain how conglomerate rocks were formed to somebody who had never heard about rocks before. Construct a diagram to explain how conglomerate rocks are formed and include labels to describe the process. (THINK: What do they need to know about rocks to understand? How can you use the diagram to help?)

6.7 Fossils are preserved in sedimentary rock

In this topic you will learn that:

- fossils are the remains of organisms preserved in rock
- scientists can use sedimentary layers to work out the age of rocks or fossils – the oldest layers of sediment are at the bottom and the youngest at the top.

fossil
the remains (or imprint) of an animal or plant preserved in rock

palaeontologist
a scientist who studies fossils

Planet Earth is 4.5 billion years old. Past events on Earth are recorded in the rocks. From about 570 million years ago, the ancestors of the different plants and animals that now populate Earth evolved. The remains of some of these life forms are captured in the rocks as **fossils**. Fossils allow specialist geologists, known as **palaeontologists**, to build up a picture of Earth's long history.



Figure 1 These fossils are found in the rock formations at Gondwana Coast in Ulladulla Harbour, NSW.

What are fossils?

Fossils are the remains (or imprints) of animals or plants preserved in rock. A fossil is therefore evidence of life in the past.

Fossilised evidence may be found in many forms, but it usually consists of the hard parts that remain after decay – bones, teeth and shells. Sometimes, softer parts of an organism are preserved (see Figure 2); even footprints or impressions of organisms are considered fossils. Palaeontologists study these remains to find clues about ancient life.

How do fossils form?

Fossils are usually only found in sedimentary rocks. These rocks are formed by the deposition of layers of sediments, such as mud, silt or sand. Any organism trapped in the mud and silt can eventually become part of the rock through the process of fossilisation. The fossils can be uncovered when the rocks are broken apart or weathered away. This process can take millions of years.

Extremely old rocks contain fossils of simple animals, whereas slightly younger rocks have fossils of animals with shells. Rocks that are younger still have fossils of fish. Only the newest rocks have fossils of mammals. The variety and complexity of life has increased as the Earth has become older.



Figure 2 If the conditions are just right, soft body parts can be fossilised.

Comparative dating

Geologists can place rocks and fossils into a date order. They work this out from the different layers of sediment in rocks. When layers of sand or mud are deposited, the oldest sediments are at the bottom; newer, or younger, sediments are deposited on top (see Figure 3).

Working out the age of rocks as being younger or older than rocks of known age is called **comparative dating** or relative dating. It is comparative because we are comparing the old with the new.

Different rocks that are the same age have the same type of fossils in them. These fossils are called **index fossils**. They are used to find rocks of the same age.

comparative dating
determining the age of rocks by comparing them with rocks of known age

index fossil
a fossil found in different rocks that can be used to determine the age of rocks

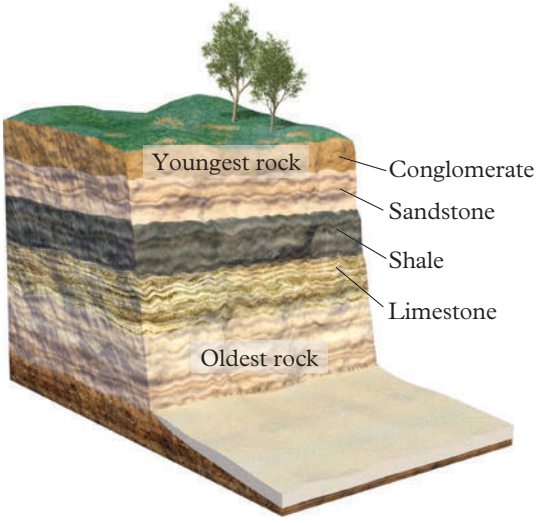


Figure 3 Comparative dating is used to determine the age of rocks and fossils.

Radioactive dating

The actual age of a fossil, measured in millions of years, is found by looking at the amount of radioactivity left in rocks. For example, uranium (U) is a radioactive substance found in many rocks. It decays to lead (Pb) at a known rate. So as rocks age, the amount of uranium decreases and the amount of lead increases. The age of rocks can be calculated by comparing the amounts of uranium and lead they contain. This is called **radioactive dating**.

The oldest rocks on Earth have been dated at 4500 million years. This method has been checked using different radioactive atoms. This age is the same as that of meteorites that crash to Earth, as well as that of Moon rocks brought back to the Earth by astronauts.

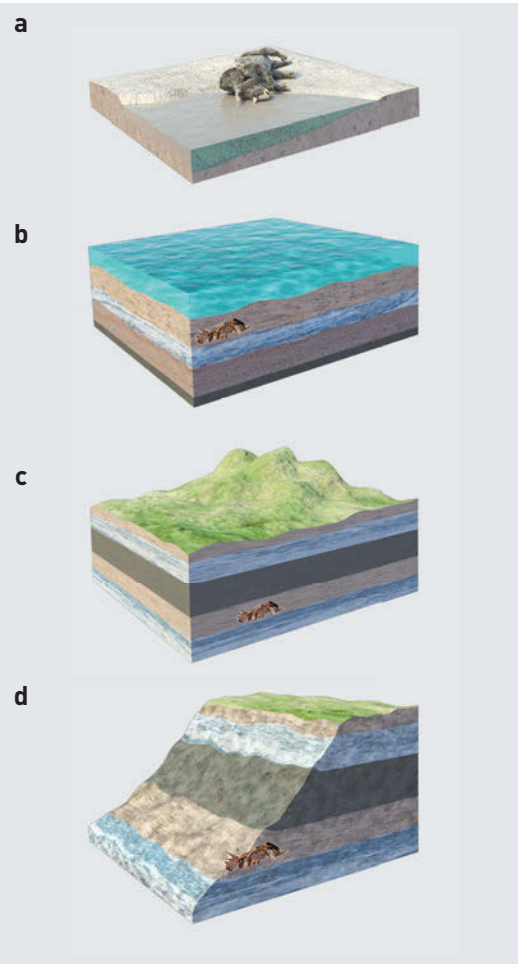


Figure 4 Formation of a fossil: **a** If an organism dies near water, it has a greater chance of being covered by sediment. **b** The sediment protects the body from predators and weathering. **c** Over millions of years, more sediment is deposited and the remains are gradually transformed into sedimentary rock. **d** Years of geological movement, weathering and erosion may eventually expose the fossil.



Figure 5 This trilobite fossil has been dated to 500 million years ago. The fossils of some trilobites are the size of beetles, whereas others are the size of dinner plates.

Interactive
Reconstructing fossils

radioactive dating
the process of calculating the age of rocks by comparing the amounts of uranium and lead they contain

Check your learning 6.7

Recall and explain

1 What is a fossil?
2 **Describe** how fossils are formed.
3 **Describe** one way that geologists can estimate how old a fossil is.

Apply and analyse

4 **Compare** the age of the dinosaur fossil in Figure 4d with a fossil found in:
- **a** the layer of rock above the dinosaur
- **b** the layer of rock below the dinosaur
- **c** the same layer of rock as the dinosaur.

Skill builder: Questioning and predicting

5 A palaeontologist came across a little fossil of a shell while she was studying a bigger fossil of a dinosaur nearby.

She asked three questions:
- 'Did this fossil come from a similar time as the dinosaur fossil?'
- 'Is this fossil better than the dinosaur fossil?'
- 'Did this fossil come from a big family?'

Which of these questions are testable questions? (THINK: Could you design an investigation to answer the question?)

6.8 The rock cycle causes rocks to be re-formed

In this topic you will learn that:

- during the rock cycle, rocks transform between igneous, sedimentary and metamorphic types
- landforms can be shaped by processes in the rock cycle.

rock cycle
the process of formation and destruction of different rock types

weathering
the breakdown of rocks and minerals by the movement of water and animals, and extremes of temperature

landform
a physical feature on the Earth's surface

The **rock cycle** is an ongoing process that describes the formation and destruction of different rock types. Over time, igneous, sedimentary and metamorphic rock types can transform into other types. This is due to natural processes, including heat, pressure, physical weathering, chemical weathering, erosion and deposition. These processes also play a role in forming and changing **landforms** on the Earth's surface.

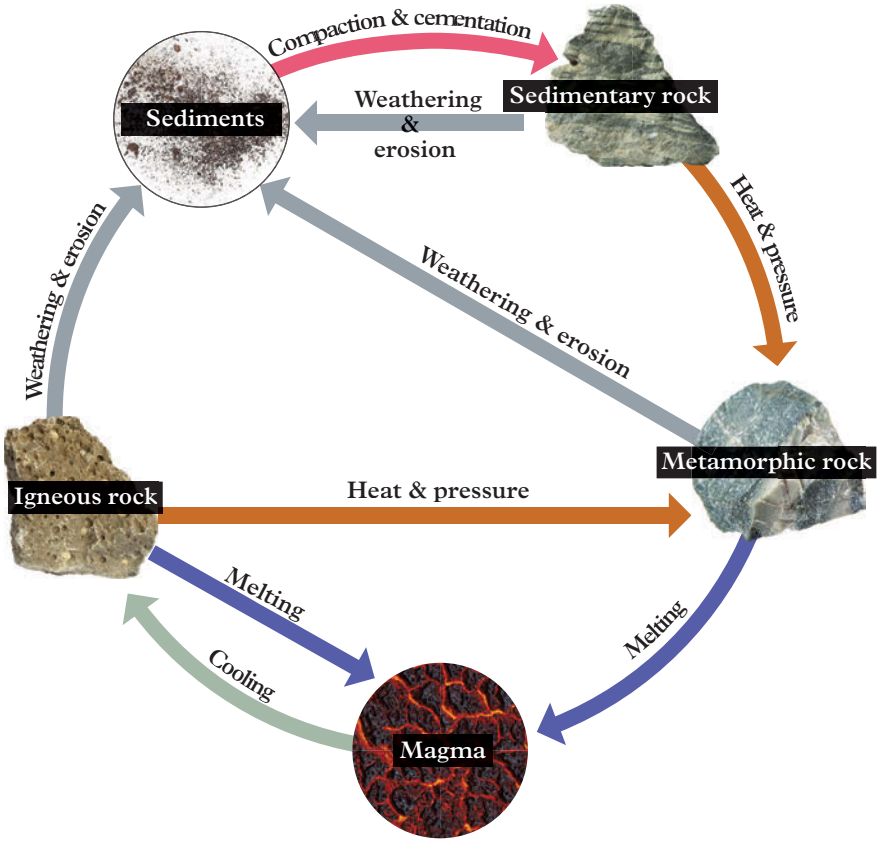


Figure 1 The rock cycle

Physical weathering

Weathering is the breaking down of rocks and minerals through the movement of water and animals, and the extremes of temperature. Mechanical, or physical, weathering occurs when a physical force is applied to a rock. It includes the breakdown of rocks by non-living things.

In desert areas, the days are very hot and the nights are freezing cold. This daily heating and cooling affect only the outside of the rock because rocks do not conduct heat very well. Sometimes the outside of the rock can peel off, just like an onion skin. This process is called onion-skin weathering, and the round rocks produced in this way are called tors.

When water freezes at night, it expands and takes up more space. When water freezes in the crack of a rock, it expands and pushes hard against the rock around it. This can make the crack larger. When the ice melts during the warmer day, water fills the crack again. The next night, ice forms again and makes the crack even larger. This process is repeated many times until part of the rock is split off. This process is called **frost shattering**.



Figure 2 Frost shattering

CHALLENGE
6.8: Modelling the rock cycle
Go to page **367**.

Erosion

Erosion is the process of taking sediment that has been broken down by the elements and moving it away to another area by wind or water. Erosion can be caused by wind, rain or water bodies, such as a river or ocean, beating at a rock's surface. For example, the Three Sisters natural rock formation in the Blue Mountains was shaped over many years. Although we only see three pillars now, there used to be seven. But erosion by wind and rain has worn the others away over time, leaving the three pillars that we see today.

Deposition

Deposition is the opposite of erosion. While erosion takes away sediment, deposition lays it down. Deposition occurs when sediment carried by wind, water or ice is moved, or 'deposited', somewhere else. This can build up layers of sediment, adding to landforms or creating new formations. For example, beaches and sand bars are formed when sand sediment is moved by the ocean and dumped in the same place to create a small landform.

Chemical weathering

Chemical weathering changes the minerals in the rock. Carbon dioxide in the air mixes with the water to form a weak acid rain (a much weaker acid than vinegar). When the acid rain falls on rocks such as limestone, a chemical reaction changes the minerals in the rock and the minerals are washed way (eroded). You can see evidence of this type of weathering in old statues.

Heat and pressure

As more and more layers form on top of the sedimentary rock, it is put under pressure. Over time the layers sink deeper to where the temperatures start increasing. Increased temperature and pressure cause physical and chemical changes in the rock, transforming it into metamorphic rock. If the temperature continues to rise, the rock will melt, turning it into its liquid form – magma.

Magma is also put under great pressure, causing it to seek any available space. Gradually it makes its way to the surface where it can cool (above or below ground) as igneous rock. Over time it is exposed to wind and water – and so the cycle continues.



Figure 3 Chemical weathering caused by acid rain

frost shattering
the process of weathering in which repeated freezing and melting of water expands cracks in rocks so that eventually part of the rock splits off

erosion
the movement of sediment to another area

deposition
the laying down of sediment

Resource
STEM activity: Can erosion be helpful?

Video
What is the rock cycle?

Check your learning 6.8

Recall and explain

1 **Describe** how sedimentary rock could become:
   a metamorphic rock
   b sediment.
2 **Define** the meaning of the term 'landform'.
3 **Outline** the process of deposition.

Apply and analyse

4 a **Identify** two landforms included in Figure 4.
   c **Account** for how you think each of these landforms may have been formed or altered by the rock cycle.

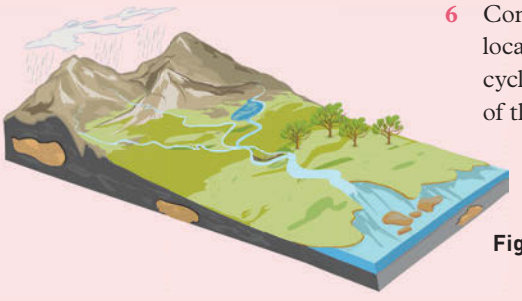


Figure 4 Various landforms

Evaluate and create

5 **Investigate** how sand dunes are formed. What processes from the rock cycle are involved?
6 Consider the landforms in your local area. **Discuss** how the rock cycle played a role in forming one of these landforms.

Skills builder: Planning investigations

7 Christopher was asked to write a report during a double period about the effect of weathering on landforms in New South Wales.
   a **Propose** the type of information Christopher should collect to complete the report on time. (THINK: Should Christopher design his own experiment to collect first-hand data? Or should he collect data using secondary sources online and in the library?)
   b **Justify** your choice.

6.9 The location and extraction of minerals relies on scientists

In this topic you will learn that:

- mining relies on the skills and knowledge from different disciplines of science.

magnetometer
an instrument that measures magnetism

Geological mapping

Geologists are scientists who study the rocks and particles that make up the Earth and the rocks that were formed. As part of this study, they produce and use geological maps using geophysical methods such as seismic testing, magnetometer testing, electromagnetic testing and gravimetric testing.

Video
Ask a scientist – Dr Jo Whittaker (Geologist)

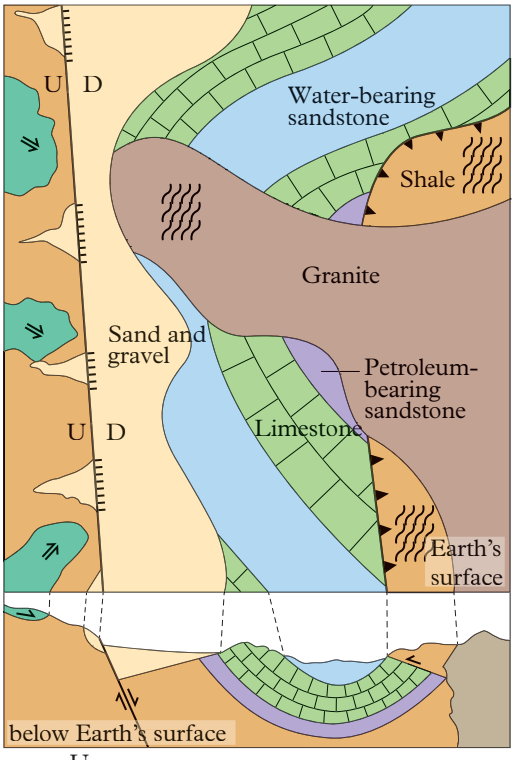


Figure 1 Geological maps allow geologists to determine the location of mineral resources that could be extracted.

Geological mapping is a special map that is designed to show all the rocks and minerals in an area. These maps are a representation of the types of rocks found under the surface of the earth. Different colours or symbols are used to indicate the types of rocks found at each location.

Geological maps can be used to locate ground water, identify possible contamination risks, predict earthquakes or volcanic eruptions, and identify energy and mineral resources and the costs of mining them.

There are a number of different ways that geological maps can be constructed. Most are a result of geophysical and geochemical testing.

Geophysical testing

Geophysical testing involves the testing of the physical properties of the earth and the atmosphere. This may include seismology (the study of earthquakes), oceanography (the study of the ocean), volcanology (the study of volcanoes) and geomagnetism (the study of the Earth's magnetic field).

Seismic geophysical testing involves the sending of vibrations into the earth. The vibrations move differently in different types of rocks. The vibrations often bounce off the different layers of rocks and travel back to the surface. Special microphones called geophones are spread across the surface of the Earth. These geophones record the returning vibrations and a computer uses the data to construct a three-dimensional (3D) map.

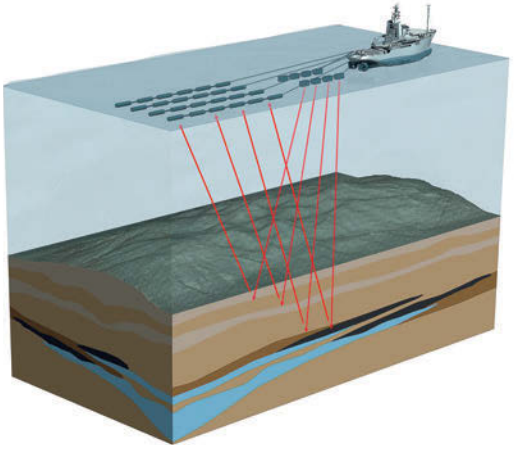


Figure 2 Seismic refraction method

Oceanography boats will often carryout geophysical surveys to locate geological structures on the ocean floor.

The presence of some metals beneath the Earth's surface can cause small changes in the Earth's magnetic field. These small changes can be picked up by **magnetometers**.

Electromagnetic pulses can be sent into the soil to detect different types of minerals. Some rocks contain minerals that do not conduct electricity, while others are affected by the electromagnetic signal. This change is detected by specialised meters carried by geophysicists.

Geochemical testing

Geochemistry involves the use of chemistry principles to identify the location and type of minerals in the earth.

Geochemical analysis is used to determine what chemicals/minerals are in the rocks. It can be used to detect the presence of petroleum products, metals and commercially valuable minerals. It can be a bit like a treasure hunt. Small samples of sediment or rocks are collected at a number of different sites and are taken back to a laboratory for chemical tests.Some samples might show a higher-than-normal level of a mineral such as copper. The geochemist will then go back to the site where those samples were located, and do further tests to locate the source of the copper.

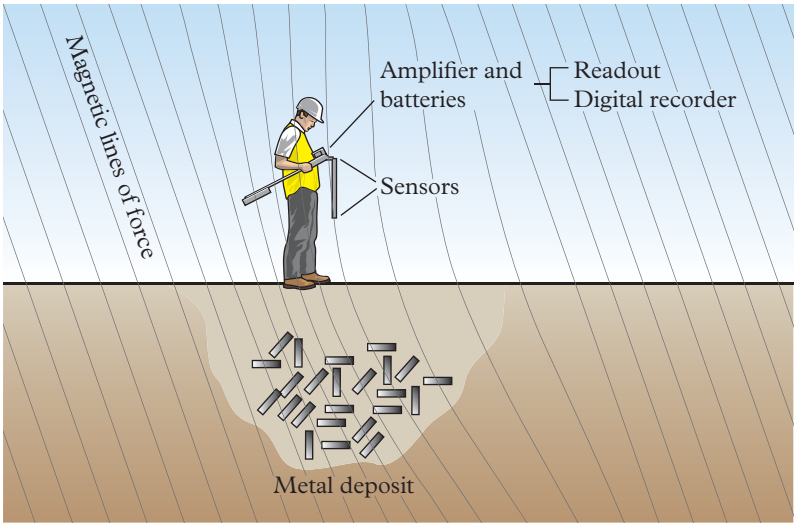


Figure 3 A magnetometer can help to detect metals in the Earth's surface by picking up changes in magnetic fields.

Extracting the minerals

Extracting the minerals can be very expensive. If the mineral is close to the surface, open mining may be used. This involves removing the surface of the soil so that the mineral can be easily extracted and taken for processing. If the mineral is deep under the Earth's surface, sub-surface mining – where tunnels or shafts are used to reach the mineral deposits – may be used. Mining engineers work to design, develop and test machines or processes that can extract minerals from the ground.

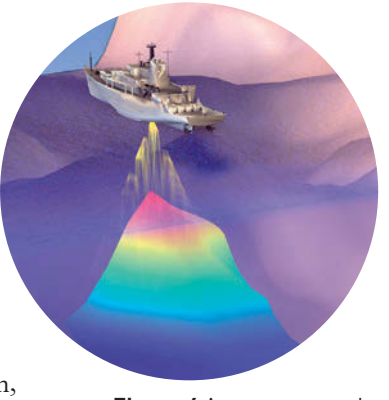


Figure 4 An oceanography boat

Check your learning 6.9

Recall and explain

1 **Describe** how the following geophysical tests detect types of rocks or minerals.
   - **a** Seismic
   - **b** Electromagnetic
   - **c** Magnetometric

2 **Identify** and **describe** two different jobs in mining.

Apply and analyse

3 What other types of jobs do you think would be involved in mining? Explain your reasoning.

4 **Explain** the difference between geophysical and geochemical testing.

Skills builder: Communication

5 Using digital technology of your choice, create an advertisement that encourages people to study one of the sciences outlined in this topic (such as geology, volcanology or oceanography).

(THINK: Who is your audience? What is your key message? What is the most appropriate text type to deliver your message?)

REVIEW

Multiple choice

1 Which part of the Earth is the lithosphere?
- **A** The inner core and outer core
- **B** The upper mantle and the crust
- **C** Just the crust
- **D** The upper core and the lower mantle

2 Fossils usually form:
- **A** in layers of sediment
- **B** in layers of igneous rock
- **C** as wind erodes layers of rock
- **D** as water erodes layers of rock.

3 Which of the following is an example of deposition?
- **A** Water in a flowing river cutting into the sides of the riverbank
- **B** Rain wearing away rock to shape a cliff face
- **C** Ocean currents laying down sediment to form a sand bar
- **D** Acid rain breaking down a marble statue

Recall and explain

4 **Describe** the structure of the Earth using the terms 'core', 'mantle', 'crust' and 'lithosphere'.

5 **Identify** the correct word to complete the following sentences.
- **a** An _____ is a mineral with a large amount of useful metal in it.
- **b** _____ rocks are formed when loose particles are pressed together by the weight of overlying sediments.
- **c** _____ rocks are formed when other types of rocks are changed by heat and pressure inside the Earth.
- **d** _____ rocks form when magma and lava from volcanic eruptions cool and solidify.

6 **Define:**
- **a** lustre
- **b** streak
- **c** hardness.

7 **Identify** the correct definition for each of the terms.

Term	Definition
Mantle	Centre part of the Earth
Crust	Layer of hot, semi-molten rock below the crust
Oceanic crust	Theory that states that the continents moved through oceanic crust
Continental crust	Less dense crust containing continents
Plate tectonics	Theory that states that large plates of the Earth's crust gradually move
Tectonic plate	Large area that may include continent and sea floor
Continental drift	Thin, semi-rigid outer layer of the Earth
Convection current	Hot liquid rock that comes up from the mantle
Magma	Dense crust under the sea floor
Core	Movement in liquids or gases caused by the rising of hot material

8 How do geologists identify minerals?

9 **Explain** the difference between intrusive and extrusive igneous rocks?

10 **Describe** how a fossil can be formed and discovered thousands of years later.

11 **Explain** why sedimentary rocks form at the Earth's surface.

12 **Explain** the difference between deposition and erosion.

Apply and analyse

13 **Outline** the relationships between igneous, sedimentary and metamorphic rocks.

14 **Examine** Figure 1, which shows the Three Sisters in the Blue Mountains. **Explain** what physical processes might have occurred to create this landform (erosion, deposition, chemical weathering or physical weathering).



Figure 1 The Three Sisters in the Blue Mountains were formed by land erosion.

15 **Contrast** magma and lava.

16 Cave systems in limestone rock follow the course of underground rivers. Why is water necessary to form caves?

17 If you were a palaeontologist searching for fossils, which types of rocks would you look for? **Explain**.

18 A kitchen scourer can be used to clean stainless-steel cutlery, but this type of scourer should not be used to clean silver-plated cutlery. **Explain** why.

19 **Explain** a way to remember which way stalactites and stalagmites grow.

20 **Deduce** why only simple fossils are found in the oldest types of rocks, whereas younger rocks have fossils of mammals.

21 **Examine** the physical properties of the rock shown in Figure 2. **Classify** this rock as igneous, metamorphic or sedimentary.



Figure 2 Classifying rocks

22 **Examine** the diagram of layers of sedimentary rock in Figure 3. **Identify** which type of fossil/s is:

- **a** the youngest
- **b** the oldest
- **c** an index fossil.

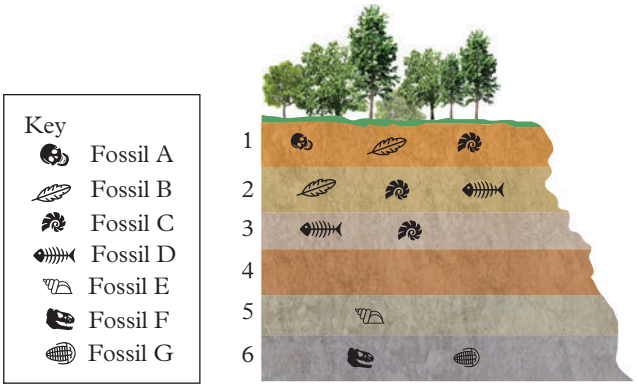


Figure 3 Layers of sedimentary rock

Evaluate and create

23 **Discuss** why we should recycle minerals. What minerals can be recycled? What forms can they be used in once they have been recycled?

24 Some famous works of art are made of marble. What are the properties of marble that make it ideal for sculpture? What are some of the properties of marble that may not make it appropriate for all works of art? **Justify** your response.

25 Create a travel brochure for NSW Tourism that promotes a landform in your state, such as a mountain or lake. **Investigate** the landform and provide a description of how it was formed and changed over time. You could include persuasive text that aims to encourage tourists to visit your chosen landform.

26 Create a story of the 'life of a rock'. Rocks change with time, as do humans. However, unlike humans, rocks are never truly 'born', nor do they 'die' – they can move through the rock cycle, covering the same stage many times in many different ways. What life does your rock experience?

Critical thinking

27 Some people say that Australia is a huge quarry. This is because Australia mines so many minerals and sells them. Working on your own, list the advantages and disadvantages of mining and selling minerals. Join with a classmate and combine your lists. Then join with another group and prepare another list containing the three best reasons for mining and the three best reasons against mining.

28 Fossils are usually found in sedimentary rock.

- **a** **Explain** why the conditions for fossil formation are better in sedimentary rock than igneous or metamorphic rock.
- **b** Do you think it would be possible for fossils to be found in igneous or metamorphic rock? **Justify** your response.

Going further

29 Look at Figure 3 below, which shows the Twelve Apostles. Use this image to describe how these rocks were formed. Prepare a poster to show how the rocks were formed and would have changed over time. How will they look in 1000 years?



Figure 3 The Twelve Apostles, located off the coast of Victoria

30 Imagine that you are a geologist who is going to discover minerals in a remote part of Australia. You will need to take a test kit to help you identify the minerals you find. What items should go into your kit to allow you to test for streak, hardness and so on?

Research

31 Choose one of the following topics on which to conduct further research. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your findings in a format that best fits the information you have found and understandings you have formed.

» Formation of oil

Oil is formed from the compression of dead marine plant material in mud over millions of years. Oil is made up of hydrocarbons, which are lighter than rock and water, so it often migrates up through porous rock towards the Earth's surface.

- » What is an oil reservoir?
- » What conditions are needed for an oil reservoir to form?
- » How is an oil field formed?
- » In what other forms is oil found?

» Gemstones

Gemstones are mineral crystal, which are cut and polished. They are often used to make jewellery and some people even collect them.

- » Which gemstones are found in Australia?
- » Which gemstones are dug up by recreational fossickers?
- » What do the gemstones look like?

» Extraction of metals

Metals are extracted from ore using a variety of methods. Some are heated, some are purified, and some are extracted using chemical processes. Why are different metals extracted using different chemical or electrical processes? Find out how some metals are extracted, such as copper and aluminium, and design a way to show the process of extraction.

Reflect

Now that you've completed this chapter, reflect on your ability to do the following:

	I can do this.	I can't do this yet.	
Describe the structure of the Earth in terms of core, mantle, crust and lithosphere.	☐	☐	Go to page 86–87.
Relate the formation of a range of landforms to physical and chemical weathering, erosion and deposition.	☐	☐	Go to page 100-101.
Outline the origins of and relationships between sedimentary, igneous and metamorphic rocks.	☐	☐	Go to page 92–97 and 100–101.
Identify that sedimentary, igneous and metamorphic rocks contain minerals.	☐	☐	Go to page 92–97.
Classify a variety of common rocks and minerals into groups according to their observable properties.	☐	☐	Go to page 88–91.
Describe the conditions under which fossils form.	☐	☐	Go to page 98–99.
Outline how geological history can be interpreted in a sequence of horizontal sedimentary layers, in which the oldest are at the base and the youngest at the top.	☐	☐	Go to page 98–99.
Describe examples to show how people use understanding and skills from across the disciplines of science in occupations related to the exploration, mining or processing of minerals in Australia.	☐	☐	Go to page 102–103.

Source: NSW Science Years 7-10 Syllabus © NSW Education Standards Authority for and on behalf of the Crown in right of the State of New South Wales, 2018.

EARTH, SUN AND MOON

How do we know about our solar system?

7

Have you ever wondered ...

- Why can you sometimes see the Moon during the day?
- Why do we have the four seasons?
- What is an eclipse?

SCIENCE UNDERSTANDING

In this chapter you will learn how to:

- explain that predictable phenomena on the Earth, including day and night, seasons and eclipses, are caused by the relative positions of the Sun, the Earth and the Moon
- demonstrate, using examples, how ideas by people from different cultures have contributed to the current understanding of the solar system
- compare historical and current models of the solar system to show how models are modified or rejected as a result of new scientific evidence
- describe some examples of how technological advances have led to discoveries and increased scientific understanding of the solar system.

Source: NSW Science Years 7–10 Syllabus © NSW Education Standards Authority for and on behalf of the Crown in right of the State of New South Wales, 2018.

Check your Student obook assess for these digital resources and more:

QuizletLive
Compete in teams to test your knowledge.

Assess quiz
Before you start this chapter, assess your science skills.

Check your Teacher obook assess for these digital resources and more:

QuizletLive
Launch a quiz for your students on key concepts in this chapter.

7.1 The Earth, Sun and Moon interact with each other

In this topic you will learn that:

- day and night occur because the Earth spins on its axis, allowing different parts of the planet to face the Sun
- during a solar eclipse, the Moon blocks out the light from the Sun.

Scientists have explored the relationship between the Earth, Sun and Moon for hundreds of years. We know the Moon **orbits** the Earth every 27 days, whereas the Earth orbits the Sun every 365.25 days. How does this cause solar or lunar eclipses?

orbit
the path taken by planets

solar energy
the energy made by atoms colliding with one another in the centre of the Sun

solar system
the system made up of the Sun and all the planets, dwarf planets, moons and asteroids that travel around the Sun or each other

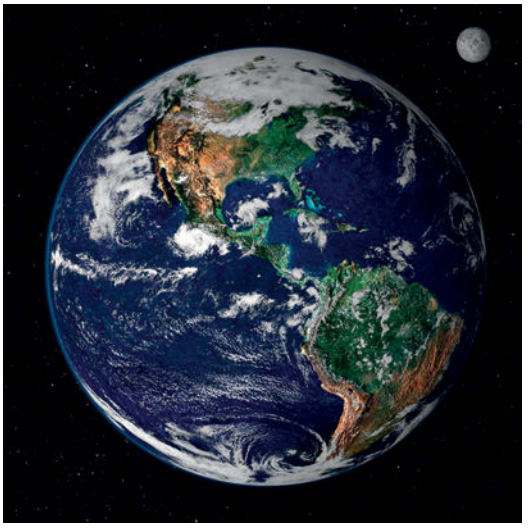


Figure 1 The Earth is held in orbit by the Sun's gravitational pull.

leap year
a year that is 366 days long, occurring every four years

axis
an imaginary straight line joining the north and south poles of the Earth

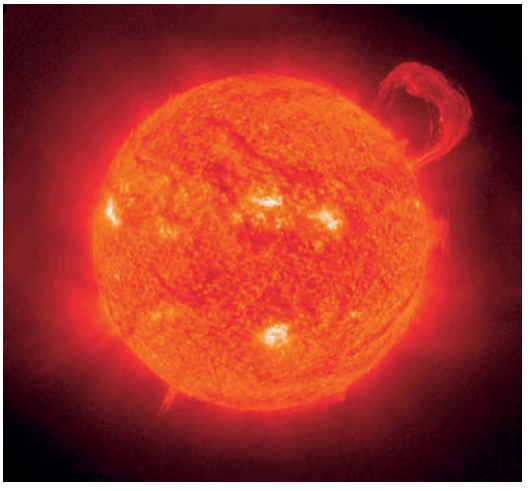


Figure 2 A solar flare is just one indicator of the powerful nuclear reactions happening inside the Sun. Solar flares begin as bright regions and result in explosions (top right).

Our Sun is a star. It is the closest star to Earth and provides all the energy for every living thing. This **solar energy** is made by atoms colliding with one another in the centre of the Sun. Without the heat and light given off by the Sun, there would be no life on Earth.

Our small planet (it is the fourth smallest in the solar system) is one million times smaller than the Sun. The **solar system** is made up of the Sun at the centre and all the planets, dwarf planets, moons and asteroids that travel around the Sun or each other. The path taken by a planet is called its orbit because of its oval or 'elliptical' shape.

A year

A year is the time it takes a planet to make one orbit around the Sun. It takes the Earth 365.25 days to complete one orbit. This means that every 4 years our calendar is one full day behind (4×0.25 days). We account for this by adding an extra day (29 February) every **leap year**.

Night and day

Day and night are caused by the Earth spinning on its **axis**, an imaginary straight line joining the North and South Poles. You can model this in your classroom. Stand facing the front of the room and turn around on the spot until you face the front once again. This is one complete rotation. The Earth takes 24 hours to complete one full rotation.

Because of its shape, only half of the Earth is exposed to sunlight at any given time; the other half is in shadow. The part facing the Sun is experiencing daytime, whereas the part facing away from the Sun is experiencing night. Because the Earth rotates, all parts of the Earth experience day and night, just at different

times. In Figure 4, it is daytime for countries on the right and night-time for those on the left. Can you tell in which countries the Sun would be rising or setting?

Have you ever watched the New Year's Eve celebrations around the world on television? The celebrations in New Zealand are always just before those in Australia. The Earth rotates west to east. We know this because, as the Earth spins towards the Sun, we see the Sun rise above the horizon in the eastern sky. Sunset occurs when your part of the Earth rotates away from the Sun. New Zealand is east of Australia, so the Sun rises in their sky first.

Solar eclipse

The Moon passes between the Sun and the Earth once every 27.3 days. Occasionally, the Moon will be in a position where it blocks some of the light from the Sun. This is known as a **solar eclipse**. During a **total solar eclipse**, the Moon blocks the maximum amount of light from the Sun and the sky goes dark for a short time during the day.

When a total eclipse is visible in Australia, people somewhere else in the world may only see a **partial eclipse**. This is when only some of the Sun's light is blocked. Because the Earth and Moon are always moving along their orbits, an eclipse takes a few minutes and then gradually passes as the Earth and Moon continue their motion.

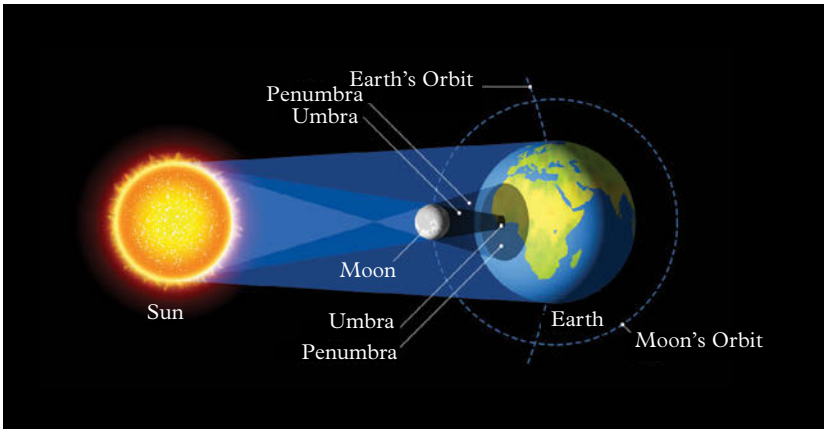


Figure 3 When the Moon is positioned between the Sun and the Earth it is called a solar eclipse.



Figure 4 The half of the Earth facing the Sun experiences day and the half in shadow experiences night.

Interactive
The path of the Sun

solar eclipse
when the light from the Sun is blocked by the Moon

total solar eclipse
when the Moon blocks the maximum amount of light from the Sun

partial eclipse
when only some of the Sun's light is blocked by the Moon

Check your learning 7.1

Recall and explain

1 **Outline** the difference between rotation and orbit.
2 **Identify** which of the following terms pair with the explanations from the list below: day, night, year.
   a Experienced by the part of the Earth that is facing away from the Sun
   b Name for the rotation of the Earth over 24 hours
   c Time for the Earth to orbit the Sun once
3 **Recall** why we have a leap year every four years.
4 **Compare** a total eclipse and a partial solar eclipse.

Evaluate and create

5 **Propose** why you (in Sydney) and a friend in Darwin could not see exactly the same solar eclipse.
6 **Investigate** and **compare** different time zones around the world. **Describe** what people in America, China, Africa and France might be doing while you are having lunch.

Skills builder: Questioning and predicting

7 **Explain** what is wrong with the question opposite. (THINK: Is it testable, specific and objective?)

'What would happen to the length of days if the length of time it took the Earth to orbit the Sun was increased?'

7.2 The Moon reflects the Sun's light

In this topic you will learn that:

- the Moon does not generate its own light but reflects light from the Sun
- a lunar eclipse occurs when the Earth moves between the Sun and the Moon.

astronomer
a scientist who studies celestial bodies



Figure 1 Galileo's observations through his telescope showed that the Moon's surface was not smooth.

phases of the Moon
changes in the shape of the Moon visible on Earth

The first scientific description of the Moon was made in 1609 by Italian **astronomer** and physicist Galileo Galilei (1564–1642), based on his observations through a telescope. At the time it was believed that the Moon had a smooth surface, which explained its ability to reflect light from the Sun. Galileo knew differently. He saw the rough, mountainous terrain and vast craters that we know cover the surface of the Moon. He even described large flat plains that we call 'maria' (pronounced 'MAHR-ee-ah'; Latin for 'seas') because they look like dark oceans. We now know these plains to be solidified lava.

Moonlight

Unlike the Sun, the Moon does not create its own light. Instead, it reflects sunlight. The amount of light reflected varies with the different **phases of the Moon**, but even the full Moon only provides a faint light that appears bluish to the human eye. We always see the same side of the Moon from Earth because the Moon rotates at the same speed as it orbits. This is just like walking around a person, making sure that you always face towards them. The Moon takes 27.3 days to completely orbit the Earth.

Sometimes, only a part of the Moon is visible. You might see half a Moon, a crescent or a fully round Moon. Sometimes the Moon can't be seen at all, even though it is in the sky. These changes in the shape of the Moon are called the phases of the Moon (see Figure 2). Of course, the Moon does not change shape – it is always round. What changes is the amount of the Moon that is lit by the Sun, which makes it possible for us to see the Moon from Earth. We are really looking at the 'day' and 'night' parts of the Moon. The Moon rises and sets, just like the Sun. The Moon rises approximately 50 minutes later from one day to the next. The Moon is always in the sky, but during the day the sky is usually so light that the Moon is hard to see.

Exploring the Moon

The Moon is the only body in space on which humans have actually stepped. It has a weak gravitational pull and very little atmosphere; therefore, there is not enough oxygen to breathe. Astronauts must wear space suits fitted with breathing apparatus.

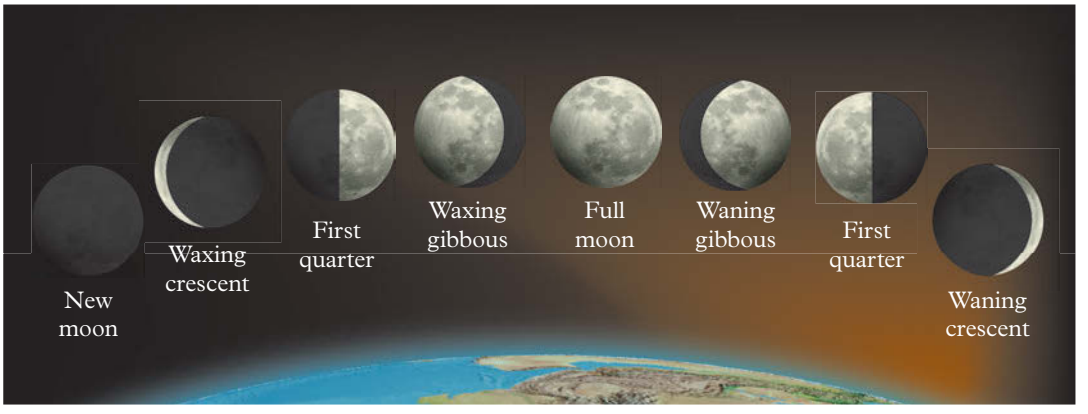


Figure 2 Phases of the Moon

CHALLENGE

7.2: Modelling the phases of the Moon
Go to page **368**.


THEIR DAY ON THE MOON

SOUVENIR ISSUE

EARLY today Neil Armstrong and Edwin Aldrin were dozing in the Eagle after their historic two-hour walk on the moon. They were due to blast off at 3.55 a.m. to rejoin the Columbia command ship after 21 hours 7 minutes on the Sea of Tranquillity.

The Sun NEWS-PICTORIAL 5c

Figure 3 The first Moon landing was televised around the world and was front-page news on 21 July 1969.

Neil Armstrong and Edwin 'Buzz' Aldrin were the first humans to walk on the Moon, in July 1969 as part of the *Apollo 11* mission (see Figure 3). They found 'kangaroo hopping' easier than walking on the Moon. The astronauts could jump higher and further because the force of gravity on them was only about one-sixth of Earth's gravity.



Figure 4 Australian scientists at the Parkes Observatory played a critical role in the Moon landing.

The surface of the Moon is made of fine grains of dust that stick together like damp sand. The footprints made by the *Apollo 11* astronauts should still be visible in a million years because there is no erosion to destroy them. However, the footprints may be covered with dust from meteor impacts.

It was possible to beam images of the Moon landing around the world because of the satellite dishes located at Honeysuckle Creek in Canberra and Parkes in New South Wales.

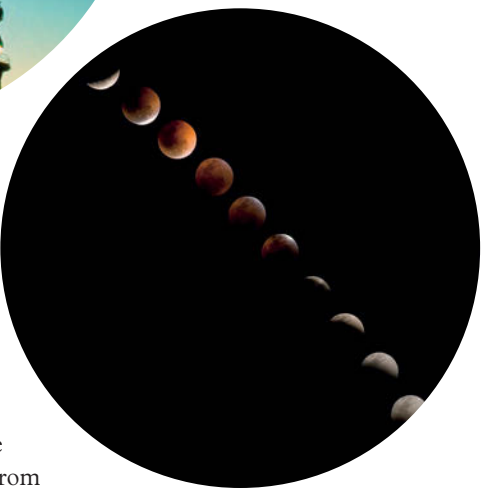


Figure 5 A time-lapse photograph of a lunar eclipse

Lunar eclipse

A **lunar eclipse** occurs when the Earth moves between the Moon and the Sun. The Moon passes into the Earth's shadow and appears dark (see Figure 5).

lunar eclipse
when the Earth moves between the Moon and the Sun

Check your learning 7.2

Recall and explain

1 True or false?
- **a** The Moon creates light.
- **b** The Moon does not supply light to the Earth.
- **c** The Moon changes shape during different phases.
- **d** The Moon is the closest body in space to the Earth.
- **e** Craters are large indentations on the Moon's surface.
- **f** Astronomers are pseudoscientists.
- **g** We can see both sides of the Moon from the Earth.

Apply and analyse

2 Greek scientist Aristotle noticed that, during lunar eclipses, the Earth's shadow was always round. **Explain** how this led him to suggest the Earth was spherical in shape.

Evaluate and create

3 Research an alternative explanation for the phases of the Moon as told by early Aboriginal and Torres Strait Islander peoples. **Discuss** how they explained the variation in the appearance of the Moon.

Skills builder: Planning investigation

4 Imagine that you have been asked to model a lunar eclipse. Write a list of materials you will need. (THINK: How can you represent the Earth, Sun and Moon? Remember to think about scale.)

7.3 Seasons are caused by the tilt of the Earth

In this topic you will learn that:

- the Earth orbits the Sun tilted on an axis
- this difference in seasons is caused by the tilt of the Earth.

equinox
the day on which day and night are the same length

The arrangement of stones shown in Figure 1 was found at Little River, Victoria, by European settlers nearly 200 years ago. The layout of 100 large boulders is thought to have been set out by the Waddawurrung people, the traditional inhabitants of the area. It is only recently that archaeologists have discovered that the 1 metre high rocks at the ends of the egg shape mark the points where the Sun sets during the middle of winter (the winter solstice) and the middle of summer (the summer solstice).

Summer

The Earth does not rotate evenly. Rather, the Earth rotates around an imaginary line (the axis) that is on an angle of 23.5 degrees. This means that, for part of the year, the southern hemisphere (including Australia) is tilted towards the Sun. The days are longer and the nights are shorter. The Sun is higher in the sky. This allows more time for the Sun's rays to hit the ground and therefore warm up the air. We experience summer. The Waddawurrung people in Victoria knew this, and placed stones that marked the place where the Sun set during the longest day (21 December). This is called the summer solstice.

Video
Seasons

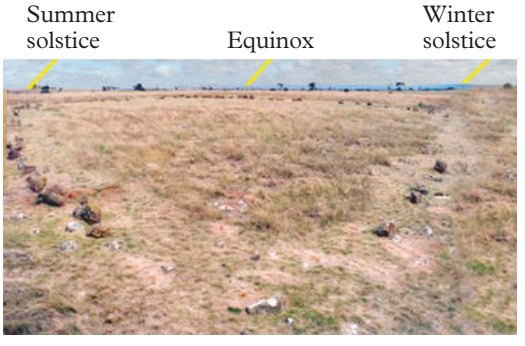


Figure 1 Early Aboriginal and Torres Strait Islander astronomers marked the movement of the Sun with waist-high stones.

Equinox

After 21 December, the Earth continues its orbit around the Sun, slowly angling the southern hemisphere away from the Sun. Twice a year (in autumn on 20 March and in spring on 22 September), the position of the Earth allows an equal length of day and night. This is called the **equinox**. The Waddawurrung people marked the sunset of these events with the equinox stone.

Winter

In winter, the southern hemisphere is angled away from the Sun. This means the Sun shines lower in our skies and for less time. As a result, there is less time for the Sun to warm up the ground and therefore the air is cooler. We experience winter. The shortest day (21 June), the winter solstice, was also marked by the Waddawurrung people.



Figure 2 The seasons are caused by the Earth's rotation at an angle of 23.5 degrees.

CHALLENGE
7.3: Modelling the seasons
Go to page **368**.

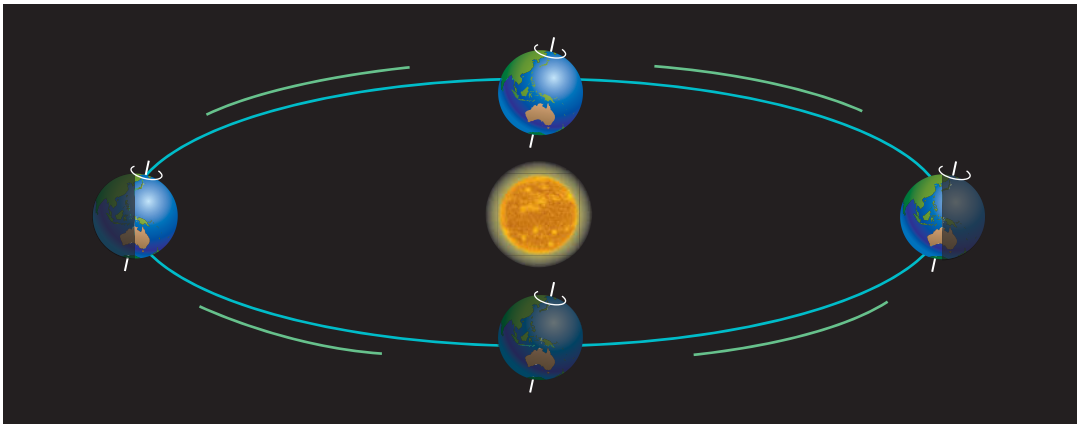


Figure 3 The Earth's rotation and orbit cause day and night, as well as the seasons.

The Waddawurrung people found a way to mark the movement of the Sun, and hence the seasons, without using telescopes or undertaking long sailing trips around the world.

The northern hemisphere's seasons are the opposite of ours, so during a northern summer there is a southern winter.

This tilt of the Earth is more noticeable in the Antarctic. In the summer, the tilt of the Earth causes the Sun to remain in the sky for five months. The Sun does not set; instead, it sits just above the horizon for the whole time. The reverse is true for winter in the Antarctic. The angle of the southern hemisphere away from the Sun means the Sun sets in May and does not rise again until July.



Figure 4 Deciduous plants change with the seasons.

Check your learning 7.3

Recall and explain

1 Match the four seasons experienced in Australia with the letters on Figure 5.

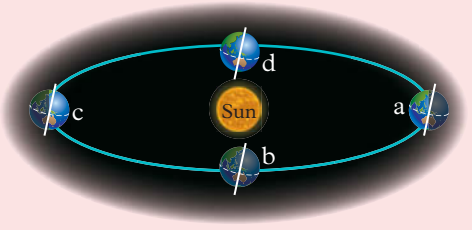


Figure 5 Earth orbiting the Sun

Identify the angle of the Earth's rotational tilt away from the Sun.

2 Use the motion of the Earth around the Sun to **explain** why January is hotter than July in Australia.

Evaluate and create

3 **Investigate** other evidence that the First Australians were aware of celestial events, such as eclipses and the phases of the Moon. Present your findings as a report or A4 poster.

Skills builder: Processing and analysing information

4 Sarah has been asked to find some reliable information online that describes what causes the seasons on Earth to change.

a Conduct your own research online to **identify** one website that you would recommend to Sarah. (THINK: What kind of website would help Sarah?)

b **Explain** why you think this site is a reliable source of information.
(THINK: Who wrote the information? When did they write it? Why did they write it?)

7.4 Our understanding of the solar system is continuously growing

In this topic you will learn that:

- Aboriginal and Torres Strait Islander peoples were the earliest astronomers
- an early understanding of astronomy was that the Earth was the centre of the universe
- heliocentrism realised that the Sun was the centre of the solar system.

Scientists across cultures have developed different ways of understanding what we can observe in the sky. This understanding continues to grow as knowledge is shared and new discoveries are made.



Figure 1 The emu-shaped dark patch in the Milky Way is one of the many constellations First Australians use as calendars to navigate and to tell stories.

geocentric model a model of the universe that places Earth at the centre of everything

The first astronomers

Aboriginal and Torres Strait Islander peoples have lived around Australia for over 65 000 years. Their understandings of the Sun, Moon and stars make them the world's oldest astronomers who still continue today. Across the hundreds of Aboriginal and Torres Strait Islander nations and communities in Australia, many different languages and cultures exist, along with different ways of observing the skies. This knowledge of the Sun, Moon and stars helped First Nations people to do things like predict weather, understand seasons and navigate. Constellations in the sky are also given meaning and linked to traditions that are passed through generations.

For the Wiradjuri people of central New South Wales, the Milky Way is the Great Celestial Emu: Gurgumin (Figure 1). The Wiradjuri people can use the position of the emu in the sky to know many things, including when emus are nesting. When the emu is directly overhead after sunset, it is the right time of year to collect emu eggs.

The ancient Mayans

The ancient Mayans were one of many ancient cultures who believed the Earth was at the centre of everything. The Maya believed that the Sun, Moon, planets and stars were gods and that, by observing their movement, they could understand the will of the gods. For example, the planet Venus was associated with the God of war, so wars and battles were planned around where Venus was positioned in the sky.

The Mayan calendar was linked closely to astronomy and is extremely accurate. The length of a solar year was exactly 365 days long, which we know today is about the length of time it takes for the Earth to orbit the Sun.

The geocentric model

The idea that the Earth is at the centre of the universe and that the planets orbit the Earth was popular for a long period of history. This **geocentric model** also seemed true to people who believed that the Earth was not moving at all – or at least it seemed that way for the people who living on it.

Ptolemy

Around 150 CE, an astronomer called Ptolemy (*c.* 100 CE – *c.* 170 CE) described another geocentric model of the universe. In his model, Ptolemy suggested that the planets orbited around a point slightly away from the Earth called 'the eccentric'. He also tried to explain why the planets appeared to travel backwards as they orbited the Earth. Ptolemy proposed that the planets travelled in small circles, called epicycles, while they orbited the Earth.

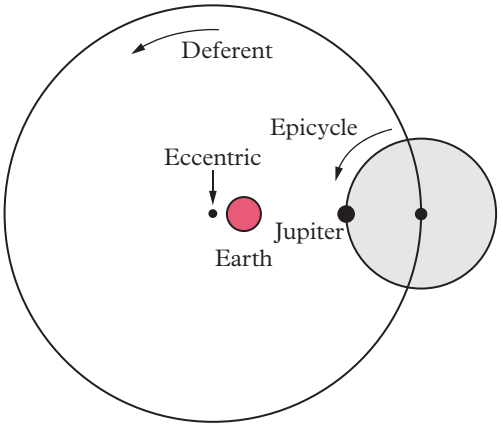


Figure 2 Ptolemy suggested that planets travelled in epicycles around a point close to the Earth called the eccentric, although we know today that this was not true.

He believed these two motions together could explain why planets sometimes appear closer to the Earth.

Early Islamic astronomy

From the 8th to 15th centuries CE, Islamic scholars developed observational techniques and established large-scale observatories that would advance astronomy further. An institute for research and translation was built in Baghdad, called the House of Wisdom, and filled with manuscripts on science and astronomy.

During this period, astronomer al-Farghānī (d. 865 CE) published *Compendium of Astronomy*, which updated and combined the work of Ptolemy with the work of other Islamic astronomers. al-Farghānī incorporated a better method of calculating the circumference of the Earth as well as the movement of the planets. This text became famous in the Islamic world and brought the ideas of Ptolemy to Western astronomers.

The heliocentric model

Polish astronomer Nicolaus Copernicus (1473–1543) was the first European scientist to argue that Earth was not at the centre of the universe. Based on his observations of the planets' motion and mathematical calculations, Copernicus proposed that:

- the planets orbited the Sun
- the Moon orbited the Earth.

Copernicus' model is called the heliocentric model (*helio* referring to the Greek god of the sun, and *centric* meaning 'at the centre').

By the 17th century, Galileo was able to use his telescope to provide evidence that the planets did in fact orbit the Sun and not the Earth.

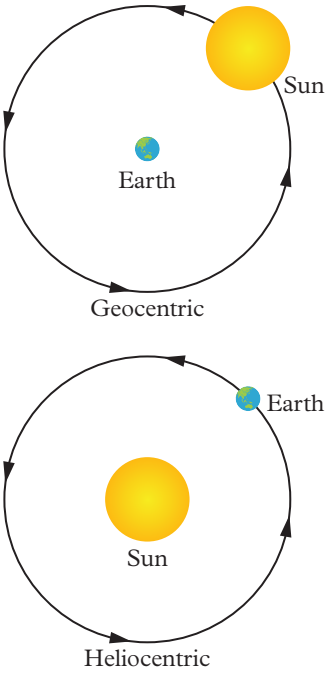


Figure 3 The geocentric model places Earth at the centre of everything. The heliocentric model recognises that Earth orbits the Sun.

Check your learning 7.4

Recall and explain

1 **Explain** how different cultures have contributed to our understanding of the solar system.

2 **Explain** the difference between the geocentric and the heliocentric views of the solar system.

3 **Identify** two key people from different cultures who have contributed to our understanding of the solar system. **Describe** their contributions.

Apply and analyse

4 **Consider** why the heliocentric model was controversial at the time it was first proposed by Copernicus and then Galileo.

5 **Explain** why the geocentric model of the solar system was rejected by the scientific community.

Evaluate and create

6 **Discuss** why people may have believed that the Earth was at the centre of the universe. What evidence was available (or not available) at the time?

7 **Investigate** more about the first astronomers – Aboriginal and Torres Strait Islander peoples. How do the traditional owners of the land that you are on understand the stars? Share your findings with your class and **explain** how this knowledge is used.

Skills builder: Problem solving

8 Wendy wondered what makes the Sun move across the sky throughout the day. She thought of two possible solutions:

- The Sun is orbiting the Earth.
- The Earth is orbiting the Sun.

Explain which of Wendy's hypotheses is correct. (THINK: How does your understanding of the solar system influence your answer?)

7.5 Advances in technology allow us to explore space

In this topic you will learn that:

- technological advances have allowed us to discover more about our solar system.

It can take many years of travel for a rocket to land on another planet. Scientists therefore need to rely on other methods to learn about space.

Astronomy

Astronomy is one of the oldest sciences, and astronomy and astrology used to be intertwined. Ancient astronomers believed that stars were permanently fixed to a heavenly sphere and never changed. They tracked the movement of the planets against these heavenly lights, which they grouped into constellations, and used these observations to calculate time and develop calendars. From this they determined the seasons and calculated the best time to plant their crops. They observed solar and lunar eclipses, and used the positions of the stars and planets to navigate the oceans.

Resource
STEM activity: Planning a mission

It is impossible to send a space probe to galaxies, stars or even gas clouds that are millions of light years from Earth and yet we know so much about these bodies. To view stars and galaxies, we use instruments such as telescopes and spectroscopes.



Figure 1 An early example of a telescope to view the stars

telescope
an optical instrument that uses lenses and mirrors to make distant objects appear closer and larger

Telescopes

A lot of information can be gathered about our Sun and distant stars by analysing the light coming from them. Analysing this light reveals information about distant galaxies and stars that would otherwise be impossible to get.

Telescopes have been used since the 17th century to view distant objects. The most common type of telescope used in astronomy is the optical telescope. This works by collecting more light than the human eye can collect, and then focusing this light using lenses or mirrors. A distant object viewed through an optical telescope becomes brighter and magnified.

The Hubble Space Telescope

Our atmosphere distorts and blocks the light coming from planets and stars. In 1990, NASA launched the Hubble Space Telescope, which orbits the Earth at 569 kilometres above our atmosphere. This has given scientists a view of our universe far beyond that of any ground-based telescope because different forms of electromagnetic radiation, such as gamma rays, X-rays and ultraviolet radiation, are available for observation.

From the images beamed back to Earth from the Hubble Space Telescope, astronomers have been able to make an enormous number of new observations. The Hubble Space Telescope is available for observations by people throughout the international astronomical community, and information and observations are available worldwide. Astronomers have been able to see galaxies developing and have estimated the age of the universe more accurately at around 13–14 billion years.

Mars mission

NASA is already planning a crewed mission to Mars. But could humans live on Mars? The Mars exploration rovers, *Spirit* and *Opportunity*, were launched in 2003 and landed on Mars in 2004 to find out more about the 'red planet'. In 2008, the *Phoenix* Mars Lander touched down on an ice sheet on the Martian surface. Operated from the Earth, its instruments took photographs of ice that was melting away. The lander's robotic arm, shown in Figure 2, scooped up soil samples. Analysis by the lander's instruments revealed traces of magnesium, sodium, potassium and, importantly, water. NASA scientists consider this discovery as a huge step forward.

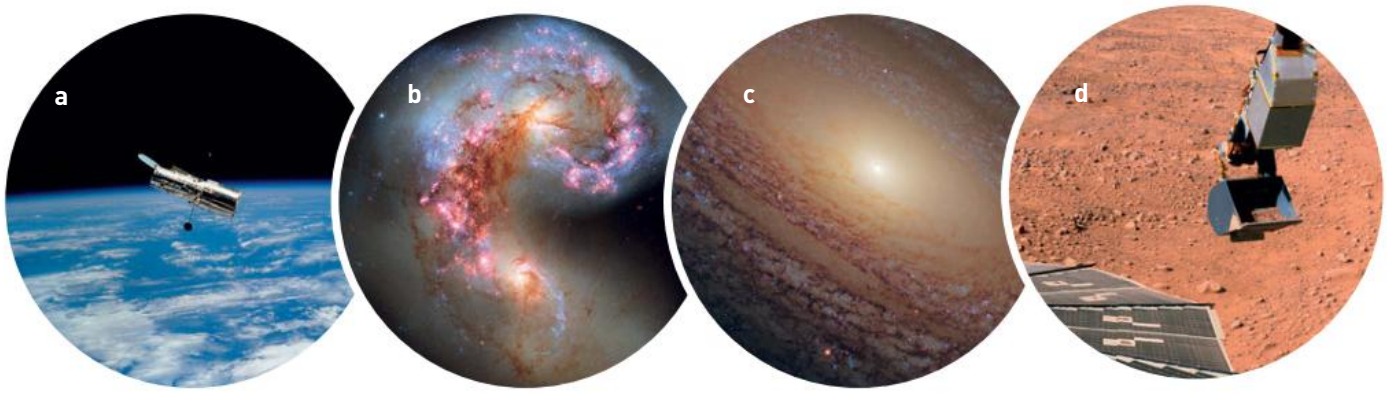


Figure 2 a The Hubble Space Telescope is in orbit around the Earth. **b** The Antennae galaxies are about 45 million light years away from the Milky Way. **c** Dark matter cannot be photographed, but it is represented in blue in this Hubble Space Telescope image of a galaxy cluster. This can be used to help understand the nature of dark energy. **d** The *Phoenix* Mars Lander delivers a soil sample to a microscope.

Space probes

Humans are also able to gather new information about space by using space probes. Typically, space probes are remotely controlled and can be launched into space to measure properties of Earth, the solar system or the universe around us.

The space probe *New Horizons* was launched by NASA in 2006. After a gravity boost from Jupiter in 2007, its six-month flyby of Pluto in 2015 produced an enormous amount of data on the planet's surface properties, geology and atmosphere that was still being analysed one year later.

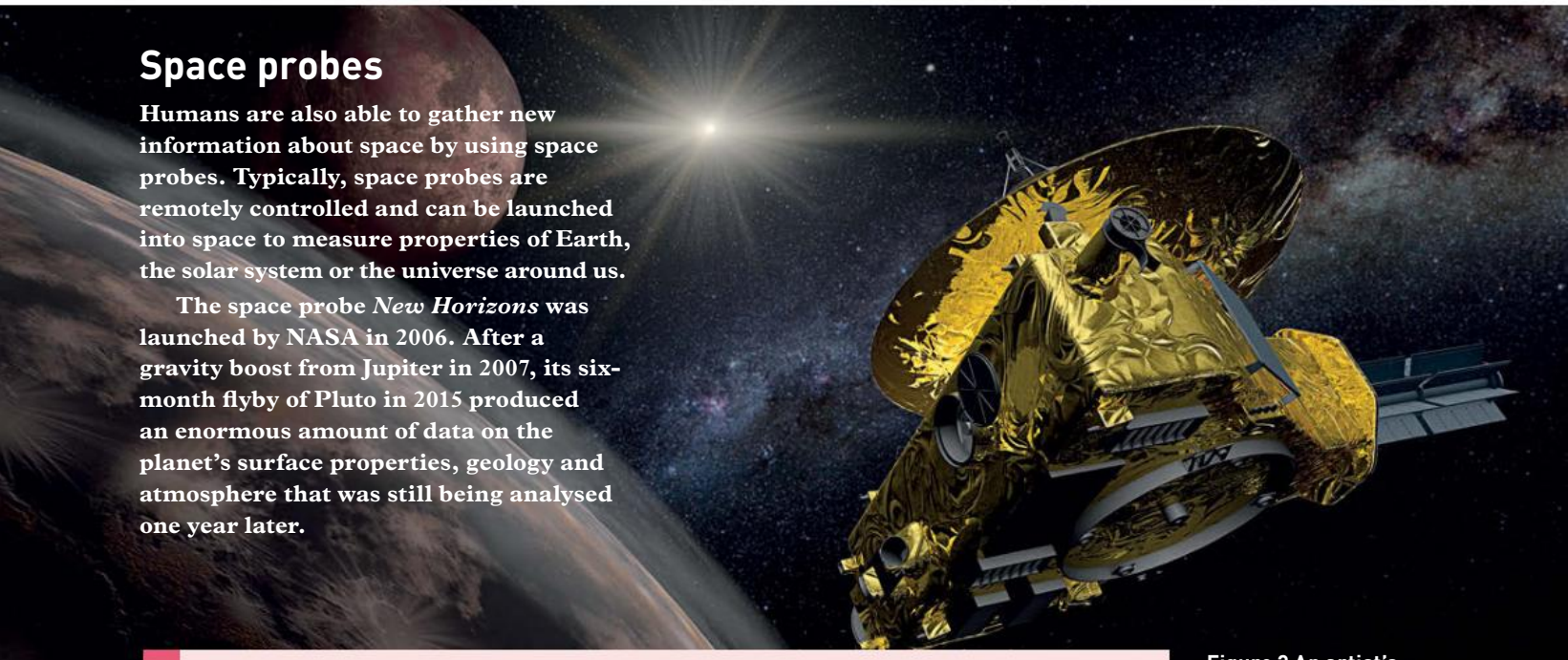


Figure 3 An artist's impression of the *New Horizons* space probe during its Pluto flyby

Check your learning 7.5

Recall and explain

1 **Explain** how a telescope helps us view distant objects.

2 **Describe** the type of information we are looking for when we launch probes into space.

3 **Describe** one discovery about our solar system that was due to advances in technology.

4 **Summarise** how our exploration of Mars has been helped by advances in technology.

Evaluate and create

5 Imagine that you are an astronomer with NASA. **Justify** the importance of maintaining the Hubble Space Telescope instead of relying on traditional telescopes on the Earth's surface.

Skills builder: Communication

6 Imagine that you have been asked to explain one of the technologies in this topic to a class of eight year olds. Draft a one-minute speech that you would give to them. (THINK: Who is your audience? What kind of language should you use to address your audience? What kind of science understanding would they have?)

REVIEW

Multiple choice

1 What is the equinox?
- **A** The longest day of the year
- **B** A day and night of equal length
- **C** A lunar eclipse that occurs every year
- **D** The shortest day of the year

2 A total solar eclipse occurs when:
- **A** the Moon blocks out the maximum amount of light from the Sun
- **B** the Earth blocks out the light on the Moon from the Sun
- **C** the Sun blocks out the view of the Earth from the Moon
- **D** a comet blocks out light from the Sun.

3 Which of the following is a description of a geocentric understanding of the solar system?
- **A** The Earth orbits the Sun.
- **B** The planets orbit the Sun.
- **C** The Sun orbits the Earth.
- **D** The Earth orbits the Moon.

Recall and explain

4 **Explain** what causes day and night.

5 **Recall** the name for one revolution of the Earth around the Sun.

6 **Recall** the term for an event when the Moon totally blocks the light from the Sun.

7 **Explain** how the Earth's tilt impacts on its seasons.

8 **Explain** how the Sun affects day and night and seasons at the Earth's two poles.

9 Look at Figure 1 below, which shows a total eclipse of the Sun as it would be seen in the middle of the day from the Earth. Draw and label a diagram to illustrate how:
- **a** a solar eclipse may occur
- **b** a lunar eclipse may occur.



Figure 1 A total eclipse of the Sun

10 **Recall** an example of how people from different cultures have contributed to our understanding of the solar system.

11 **Recall** which culture/s are considered the first astronomers.

12 **Identify** one key technology that has advanced our understanding of the solar system.

Apply and analyse

13 During summer in Australia, what is the season in Norway?

14 Figure 2 shows how the seasons occur. Answer 'A' or 'B' to each question.

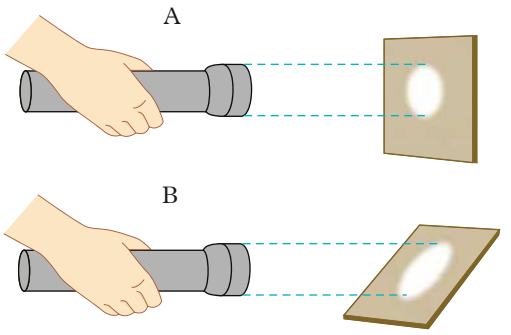


Figure 2 How the seasons occur

- **a** Which gives the more spread-out light?
- **b** Which of the two drawings represents summer?
- **c** If the piece of card was the Earth, in which case would the Sun be most overhead?
- **d** If the piece of card was the Earth, which one would give warmer days?

15 The Persian calendar celebrates the New Year at the moment the Sun crosses the celestial equator on approximately 21 March each year. In 2014 it was celebrated at 4 am on the east coast of Australia. In 2015 it was celebrated at 10 am. **Explain** why the exact time of the New Year changes from one year to the next.

16 **Compare** the geocentric model of the solar system with the heliocentric model of the solar system. How do these models compare with our understanding of the solar system today?

17 **Describe** the purpose of the Hubble Space Telescope.

Evaluate and create

18 **Examine** Figure 3 and answer the following questions.

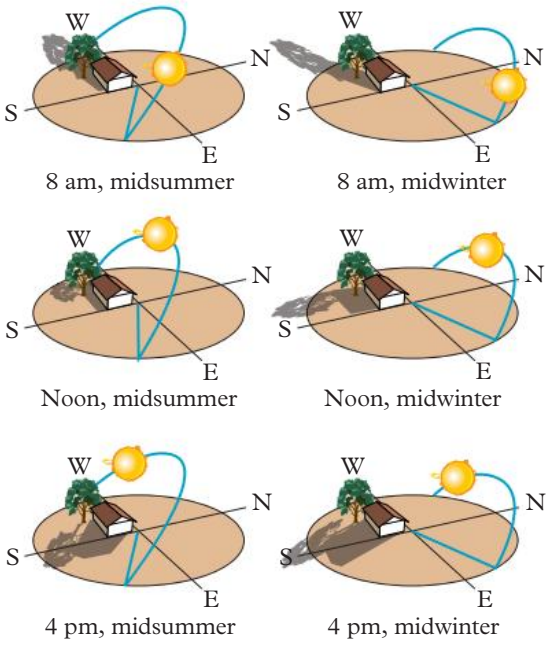


Figure 3 The path of the Sun across the sky in winter and summer

- **a** In which season do we get the longest shadows?
- **b** Which season gives the least opportunity for solar heating?
- **c** In which season does the Sun travel furthest across the sky?
- **d** On which side of the house is it best to grow plants that like sunlight?
- **e** If a plant is growing on the eastern side of a house, will it receive sunlight in the morning or afternoon?

19 A student claims that the Moon is a mini Sun that shines at night. **Evaluate** their claim. Are they correct? Provide evidence to support your argument.

20 **Discuss** why the geocentric model of the solar system would have been popular with early astronomers.

21 **Construct** a timeline to represent the development of our understanding of the solar system. **Outline** the different perspectives from different cultures, including the knowledge of one culture you have researched (that is not explained in this chapter).

22 Some early European settlers claimed that the First Australians did not use any sciences. Provide evidence to refute this claim.

Critical thinking

23 Find data for the sunrise and sunset times over seven days in summer and winter. From this information, **calculate** the length of the day and the length of the night. Present your findings in a table. What do you notice about the length of the days and nights for each season? How can you explain the difference?

24 Geocentrism was the belief that the Earth is at the centre of the universe. Consider why someone might hold this view.

- **a** Give two reasons why someone may think the Earth is at the centre of the universe.
- **b** Referring to one or more technological advances, **explain** why we know geocentrism is incorrect.

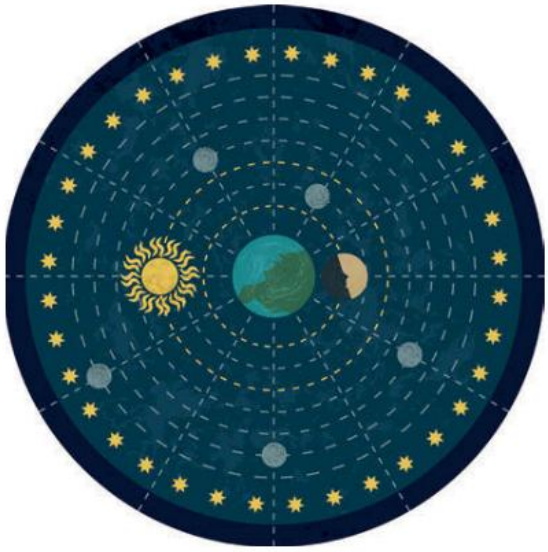


Figure 4 According to geocentrism, the Earth is in the middle of the universe and the Moon, Sun, planets and stars orbit it.

25 Some people alive today believe the Earth is flat. Develop an argument to explain why they would be wrong.

Going further

26 Consider how one culture's knowledge or understanding of the solar system has been maintained or lost throughout history. How has evidence of their beliefs been recorded? Has our modern understanding built on theirs in any way?

27 Could humans colonise the Moon? **Discuss**.

Research

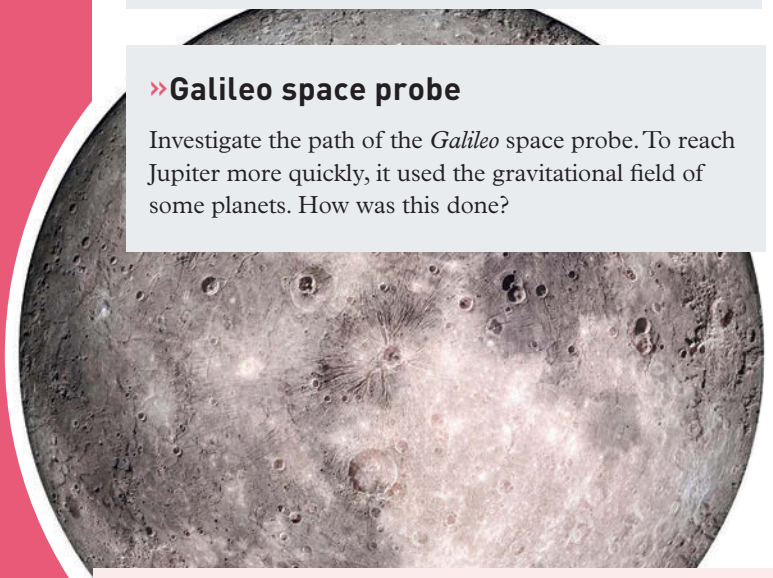
28 Choose one of the following topics on which to conduct further research. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your findings in a format that best fits the information you have found and understandings you have formed.

»The search for extraterrestrial intelligence

Astronomers are also involved in a Search for Extraterrestrial Intelligence (SETI). Find out what instruments astronomers are using in this search. How will these instruments help them find extraterrestrial intelligence? What are they looking for exactly? Will it be in human form? You, too, can use your computer to become a part of this search.

»Galileo space probe

Investigate the path of the *Galileo* space probe. To reach Jupiter more quickly, it used the gravitational field of some planets. How was this done?



»Mission to the Moon

The huge *Saturn* rocket that took *Apollo 11* to the Moon was an extremely powerful system in its day. The rocket had three 'stages', and each carried its own fuel and dropped off as the rocket went higher in the sky. The rocket carried the 'lunar lander', which was itself a very complicated piece of technology. Investigate the *Saturn* rocket and build your own model to explain each stage and how it performed.

»The far side of the Moon

Because the Moon rotates at the same rate as the Earth, we never see the far side of the Moon from Earth. So, what is it like? Is it the same as the near side of the Moon? The far side of the Moon has been seen. Find out who saw it and how, what it's like compared with the side we know from Earth, and what future missions to the Moon might be tasked with.

»The first astronomers

First Nations peoples in Australia are the world's oldest astronomers. They observe the sky and are able to give meaning to the stars, Sun and Moon. Find out more about the First Nations people in your area. Can you find any resources that show how the sky plays a role in their culture?

Figure 5 Humans have been observing the skies for thousands of years.

Reflect

Now that you've completed this chapter, reflect on your ability to do the following:

	I can do this.	I can't do this yet.	
Explain that predictable phenomena on the Earth, including day and night, seasons and eclipses, are caused by the relative positions of the Sun, the Earth and the Moon.	☐	☐	Go to page 108–113.
Demonstrate, using examples, how ideas by people from different cultures have contributed to the current understanding of the solar system.	☐	☐	Go to page 114–115.
Compare historical and current models of the solar system to show how models are modified or rejected as a result of new scientific evidence.	☐	☐	Go to page 114–116.
Describe some examples of how technological advances have led to discoveries and increased scientific understanding of the solar system.	☐	☐	Go to page 115–116.

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RESOURCES

How do we manage the Earth's resources?

8

Have you ever wondered ...

- Where do we get electricity from?
- Why do people have such different opinions on fossil fuels?

SCIENCE UNDERSTANDING

In this chapter you will learn how to:

- classify a range of the Earth's resources as renewable or non-renewable
- outline features of some non-renewable resources, including metal ores and fossil fuels
- describe uses of a variety of natural and made resources extracted from the biosphere, atmosphere, lithosphere and hydrosphere
- investigate some strategies used by people to conserve and manage non-renewable resources, e.g. recycling and the alternative use of natural and made resources
- discuss different viewpoints people may use to weigh criteria in making decisions about the use of a major non-renewable resource found in Australia
- outline the choices that need to be made when considering whether to use scientific and technological advances to obtain a resource from Earth's spheres.

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Check your Student obook assess for these digital resources and more:

QuizletLive
Compete in teams to test your knowledge.

Assess quiz
Before you start this chapter, assess your science skills.

Check your Teacher obook assess for these resources and more:

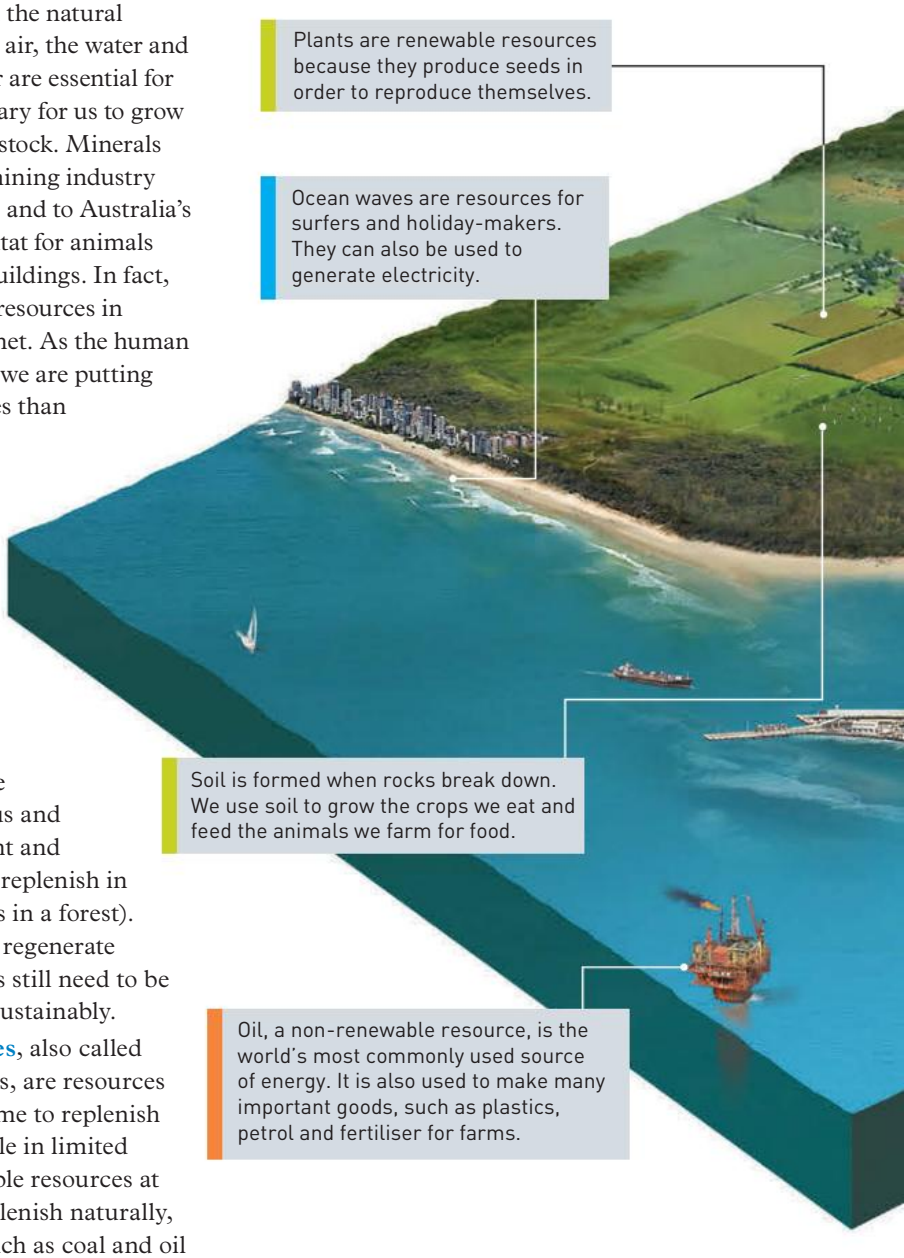
QuizletLive
Launch a quiz for your students on key concepts in this chapter.

8.1 Resources on Earth are either renewable or non-renewable

In this topic you will learn that:

- resources can be classified as renewable or non-renewable.

Humans have always relied on the natural resources of the Earth – in the air, the water and the ground. Oxygen and water are essential for keeping us alive. Soil is necessary for us to grow food for ourselves and our livestock. Minerals from the Earth that feed the mining industry are essential to manufacturing and to Australia's economy. Forests provide habitat for animals and timber products for our buildings. In fact, humans have found and used resources in almost every corner of the planet. As the human population continues to grow, we are putting more pressure on our resources than ever before.



Types of resources

Resources on Earth can be classified into two major groups:

- renewable resources
- non-renewable resources.

renewable resource
a resource that is made naturally and is available in an almost unlimited amount

Renewable resources are either available in a continuous and unlimited supply (like sunlight and wind) or are able to naturally replenish in most conditions (like the trees in a forest). Despite the fact that they can regenerate naturally, renewable resources still need to be managed carefully and used sustainably.

non-renewable resource
a resource that is limited because, once used, it takes a long time to replace

Non-renewable resources, also called long-term renewable resources, are resources that take an extremely long time to replenish and are therefore only available in limited supply. If we use non-renewable resources at a faster rate than they can replenish naturally, they will run out. Minerals such as coal and oil are non-renewable resources.

Environmental resources

An overview of the many types of environmental resources

- Continuous resources
- Renewable resources
- Non-renewable resources

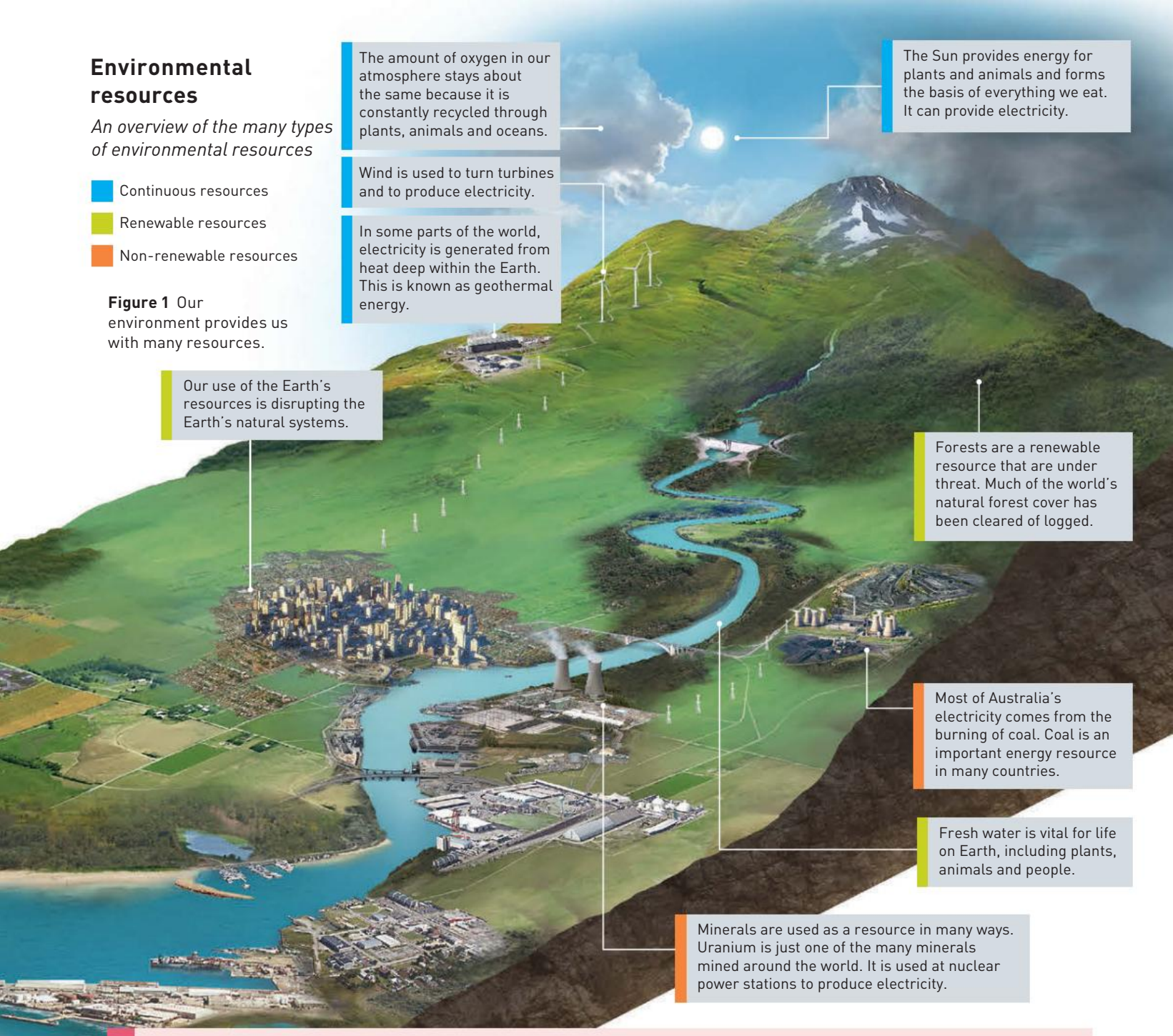


Figure 1 Our environment provides us with many resources.

Check your learning 8.1

Recall and explain

1 **Identify** the two main types of resources.

2 **Recall** one renewable resource that is continuous and one that can be replenished.

3 **Identify** all the non-renewable resources you have used in the past hour.

Apply and analyse

4 **Examine** the resources shown in Figure 1. Based on your understanding, **explain** which you think are well managed in Australia today and which are not well managed. **Justify** your answer.

Evaluate and create

5 **Evaluate** Figure 1. Which resources do you think are the most important? **Justify** your response.

6 Conduct some research to **compare** the way we manage resources today with the way Aboriginal and Torres Strait Islander peoples traditionally managed the Earth's natural resources.

Skills builder: Planning investigations

7 Imagine that you had to investigate one of the resources displayed in Figure 1. Which would be the easiest to design a testable investigation? **Justify** your response. (THINK: How would you access these resources? What kind of equipment would you need?)

8.2 Renewable resources can be quickly replaced

In this topic you will learn that:

- renewable resources can be replaced at the same rate they are used
- any resources that take a long time to be replaced are called non-renewable.

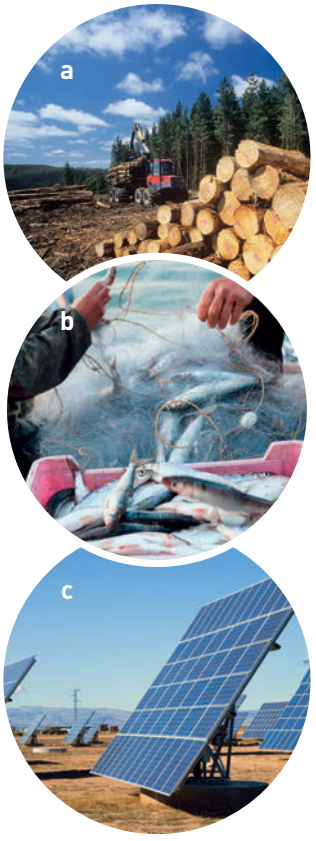


Figure 1 Some of the Earth's natural resources: **a** timber, **b** fish and **c** solar energy.

energy resource
a resource that can be used for the production of energy

greenhouse gas
a gas (carbon dioxide, water, methane) in the atmosphere that can absorb heat

Our supply of energy resources is running out, so we need to consider how we use energy more carefully now so that there is enough energy in the future.

Renewable and non-renewable resources

When you learnt how to light the gas in a Bunsen burner in chapter 1, you were using a non-renewable resource. If you burnt 1 litre of gas, there is 1 litre less of that gas in the world. Many non-renewable resources are continually being made, but on a time scale of hundreds of thousands or even millions of years. It is for this reason they are more accurately called 'long-term renewable resources' because they do eventually replace themselves. But, practically, they are non-renewable in our lifetime. If we continue to use a non-renewable resource and it is not recycled, it will run out for humans.

It is estimated that Australia's brown coal will last for another 500 years. By 2030, coal is still expected to be our main energy resource, but with a shift to resources such as gas and renewable energy such as wind.

Renewable resources are made naturally and are available in an almost unlimited amount. Solar energy is a renewable resource: an unlimited amount of it is available while the Sun shines in the sky. Of course, if the weather is cloudy, solar energy is not available; therefore, it can have some disadvantages too. Other examples of renewable resources include clean air, timber and fish. Given the right conditions, they will be available if we don't use them too fast. We need to consider the consequences of taking too much.

Australia's energy resources

Australia has a variety of **energy resources**. For a long time, we have relied on energy resources such as coal and petrol for our energy needs.

According to recent research, Australia is one of the highest **greenhouse gas** emitters in the world. Using non-renewable energy resources for transport and generating electricity for use around the home make up approximately one-fifth of these emissions.

Table 1 Use of Australia's energy resources

Resource	Use	Percentage of total electricity production 2019 (%)
Coal (brown and black)	Electricity generation	56.4
Liquefied petroleum gas (LPG)	Transport fuel	0
Uranium	Exports	0
Natural gas	Electricity generation	20.5
Oil products	Transport fuel	2.2
Bioenergy	Transport fuel, heat and electricity generation	1.3
Wind	Electricity generation	7.4
Hydro	Electricity generation	5.4
Solar	Solar heating and electricity generation	6.8
Geothermal	Demonstration projects only	0
Wave, tidal	Demonstration projects only	0

Source: Adapted from *Australian Energy Resource Assessment*, Geoscience Australia.

CHALLENGE

8.2: Can you increase the output of a power station? Go to page **369**.

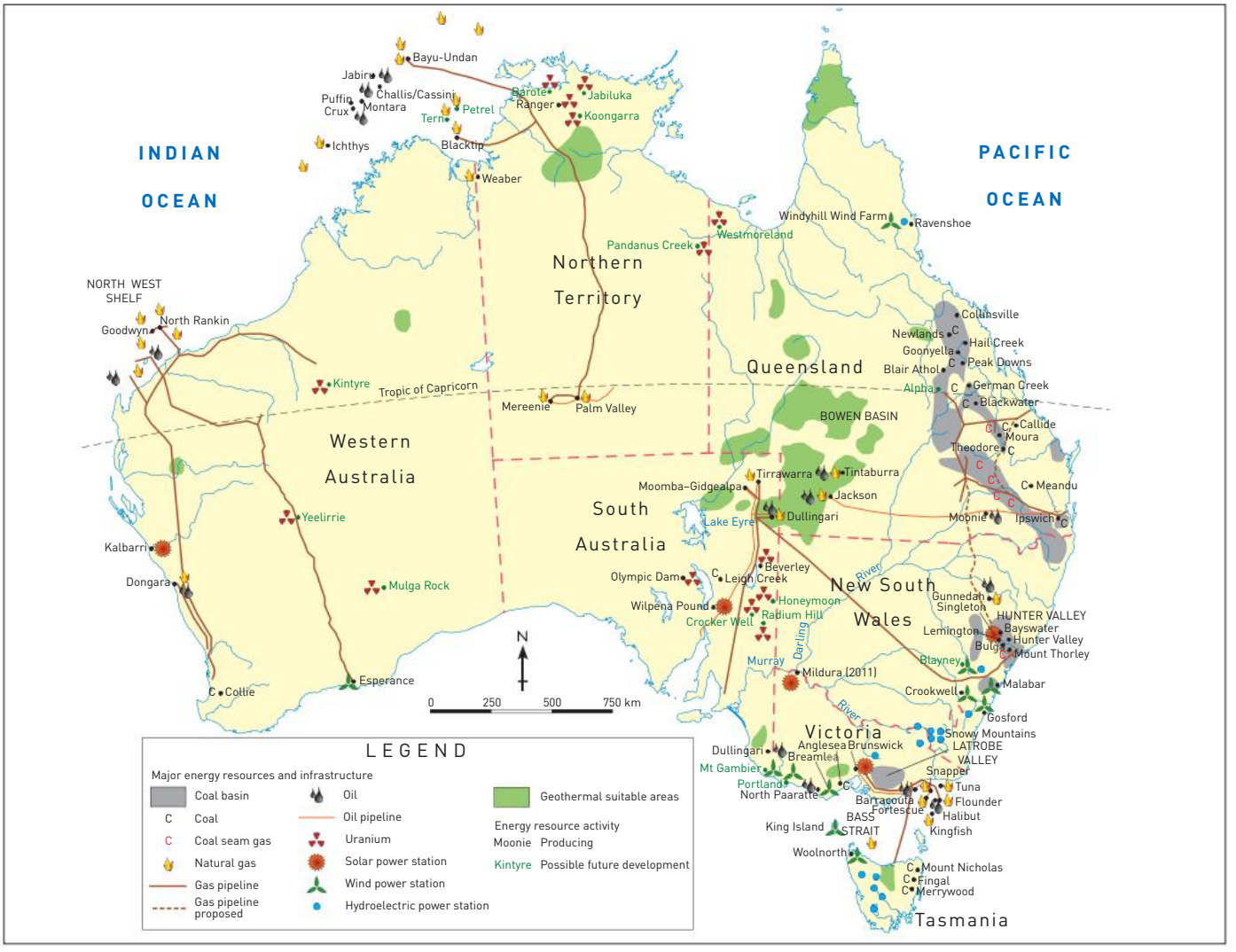


Figure 2 The location of Australia's energy resources

Coal-fired power stations

Coal-fired power stations burn coal to produce electricity. When coal is burnt, heat is released. This heat is used to boil water to make steam. The steam is used to make a turbine spin.

A turbine is a large wheel with angled sections called vanes, like a propeller. The turbine is connected to a generator. A generator converts the movement from the turbine into electrical energy.

Check your learning 8.2

Recall and explain

1 How long does a non-renewable resource last? **Explain** your answer.

2 How long does a renewable resource last? **Explain** your answer.

3 What is the time scale for formation of non-renewable resources? What about renewable resources?

Apply and analyse

4 **Explain** why the time scale of a resource is an important issue.

Skills builder: Processing and analysing information

5 **Examine** Figure 2.

a What energy resources are found in Western Australia or off the West Australian coast? (THINK: What can the legend tell you?)

b **Explain** why the coal mines in Australia are located where they are. (THINK: Can you see any relationships between features on this map?)

8.3 Renewable resources can be harnessed to provide energy

In this topic you will learn that:

- energy can be obtained from the atmosphere, hydrosphere, lithosphere and biosphere.

Resources can provide a source of energy to meet our needs. There are many resources that can provide unlimited amounts of energy to help us generate electricity, heat our homes or to transport our goods and services.

Resource
STEM activity: I'm a big fan

atmosphere
a layer of gases that surround the Earth and other planets

Energy from the atmosphere

The **atmosphere** provides us with air to breathe. Changes in air pressure and temperature in the atmosphere can create wind.

A very important step in generating electricity is turning a turbine. Fossil fuels are burnt to produce steam to turn a turbine. Wind can also turn a turbine without producing steam and without emitting carbon dioxide.

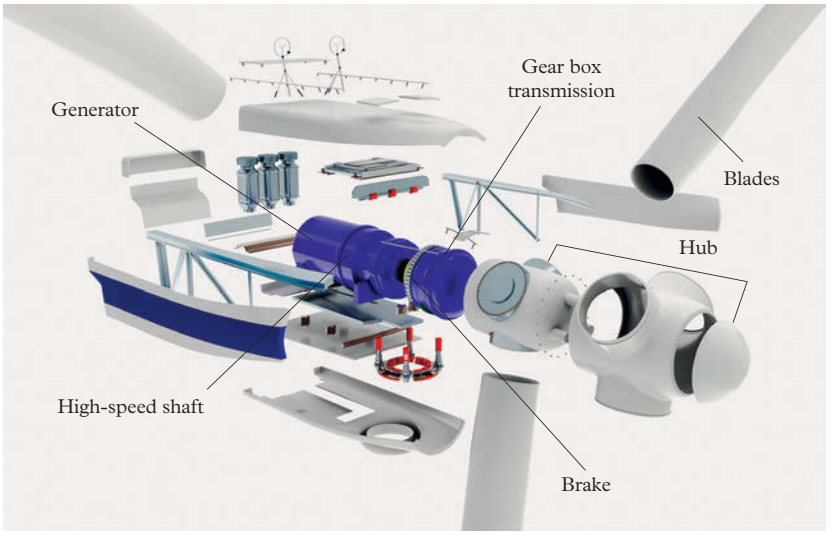


Figure 1 The parts of a wind turbine

wind turbine
a wheel with blades that turns in the wind

wind farm
a large group of wind turbines in the same location

To generate a significant amount of energy, many **wind turbines** are placed in long rows in a wind farm. **Wind farms** must be in windy locations. The stronger the winds, the faster the turbines turn and the more energy is produced.



Figure 2 A wind farm in Australia

People hold different views about wind farms. Some people don't want to look at rows and rows of wind turbines and say that the turbines are noisy and pose a threat to birds. Others think they are a good way to reduce pollution, and that the modern technology is beautiful.

Energy from the hydrosphere

The **hydrosphere** refers to all the water on the planet – on the surface of the planet, underground and in the air. We can use energy from the hydrosphere as a renewable resource.

CHALLENGE
8.3: Can you increase the power of solar cells?
Go to page **370**.



Figure 3 The Snowy Mountains hydroelectric scheme

Hydroelectric energy

Hydroelectric energy (*hydro* means 'water') is produced by falling water that turns turbines to produce electricity. It accounts for approximately 19 per cent of the world's energy production. Hydroelectric schemes need a constant water supply and are often built in high-altitude areas, like mountains. The water supply is held in dams and then released to cause fast-flowing water, which turns the turbines efficiently. Hydroelectric power in Australia meets approximately 4.5 per cent of our electricity needs. The main hydroelectric installations are in Tasmania and in the Snowy Mountains in New South Wales.

Tidal and wave power

Have you ever been to a surf beach and experienced the ferocity of the waves? Swimming at a surf beach can be quite dangerous. It has been estimated that **wave energy** alone could power the entire Earth five times over! The only problem has been working out how to do it. Wave energy uses the energy of waves to drive air turbines (see Figure 4).

Tidal energy can also be used to drive turbines in the water to generate electricity. The major disadvantage of tidal power is that it only provides a relatively small amount of electricity and has a negative impact on the nearby natural environment. The world's largest tidal power station is in France.

hydroelectric energy
energy produced by falling water that turns turbines to generate electricity

tidal energy
energy produced using the tides to drive turbines in the water

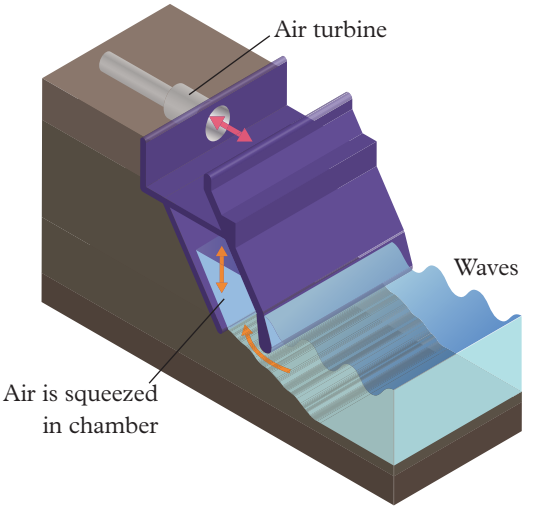


Figure 4 How wave power drives air turbines

hydrosphere
the total amount of water on a planet

wave energy
energy produced using the power of waves to drive air turbines



Figure 5 Superheated water is produced at the geothermal power plant in Birdsville, Queensland.

Energy from the lithosphere

geothermal energy
energy that comes from heat beneath the Earth's surface

As we learnt in chapter 6, the lithosphere is the uppermost part of the mantle and the Earth's crust. **Geothermal energy** comes from heat beneath Earth's surface. The super-heated liquid rock under the Earth's surface is called magma (this is called lava when it erupts from a volcano). Magma heats the layers of rock above and below it. This heat is geothermal energy and some of it is released as steam. The steam can be used to turn a turbine in a generator, producing electricity.

Energy from the biosphere

biosphere
the regions of the lithosphere, hydrosphere and atmosphere inhabited by living organisms

biomass
plant or animal material we use from the biosphere to produce energy

biofuel
a fuel produced from biomass

ethanol
a type of alcohol that can be used for fuel

The **biosphere** refers to the global ecosystem of living things on the planet – in the air, on the land, underground or underwater. The plant or animal material we use from the biosphere to produce energy is called **biomass**. For example, the wood you burn on a fire is biomass because it has come from a living tree.

Biofuels can be used to replace non-renewable fuel, like petrol to run cars. The most common form of biofuel is **ethanol**, which is a type of alcohol. Ethanol is commonly made by fermenting sugars found in crops such as corn, canola or sugar cane.

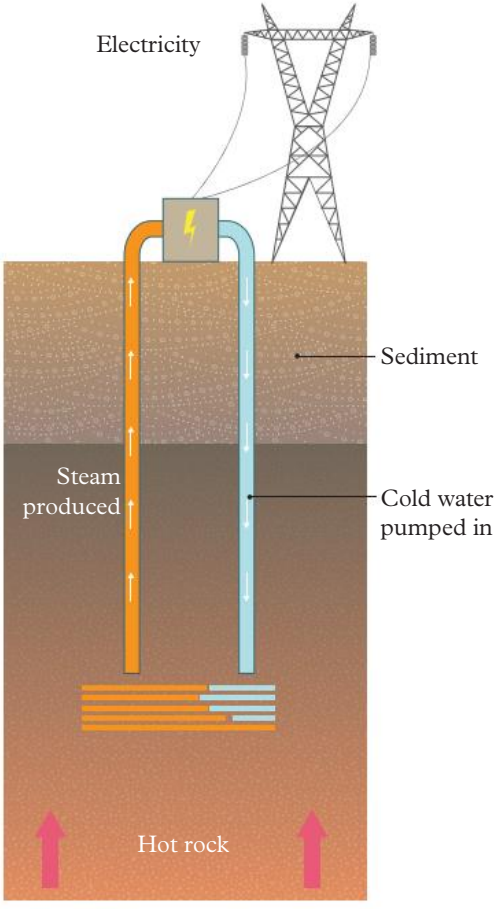


Figure 6 How hot dry rock technology works



Figure 7 Canola can be harvested as a source of biofuel.

Energy from the Sun

In Australia we are familiar with **solar power** for things such as hot water, outdoor lighting and school zone speed limit signs.

Solar energy is made when **solar cells** (or solar panels) convert sunlight into electrical energy. Once set up, they do not give off greenhouse gases. However, there are environmental impacts in their construction and disposal.

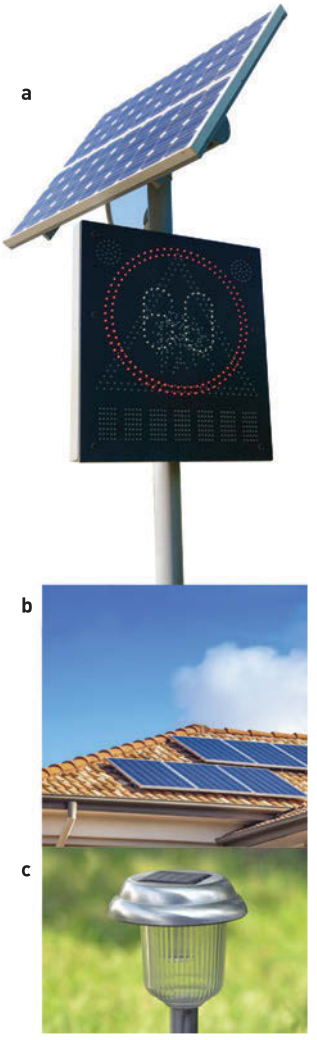


Figure 8 Solar power has many uses (**a**–**c**). Which of these have you seen?

solar power
energy from the Sun

solar cell
used to transform sunlight directly into electrical energy; usually in the form of a panel; also known as a solar panel

Check your learning 8.3

Recall and explain

1 **Identify** two advantages of hydroelectric power over fossil fuels.

2 **Explain** how a renewable resource can be obtained from the biosphere.

Apply and analyse

3 A large group of wind turbines in the same location is called a wind farm. Where do you think is the most suitable location for a wind farm? **Identify** the important features of your chosen location.

4 **Suggest** why most wind turbines are mounted on towers 40–100 metres high?

Evaluate and create

5 Coal-fired power stations in Victoria run 24 hours a day, 7 days a week. Is wind power as reliable a source of energy as coal? **Justify** your answer.

Skills builder: Questioning and predicting

6 **Predict** what would happen to a solar panel's power-producing abilities in the following scenarios. **Explain** your reasoning. (THINK: Use your understanding of how solar power works.)

a It was placed in the shade instead of the sun.

b It was placed on a roof of a skyscraper.

8.4 Non-renewable resources are limited

In this topic you will learn that:

- non-renewable resources, also called long-term renewable resources, take a long time to replenish
- mining and burning fossil fuels can have a negative impact on the environment.

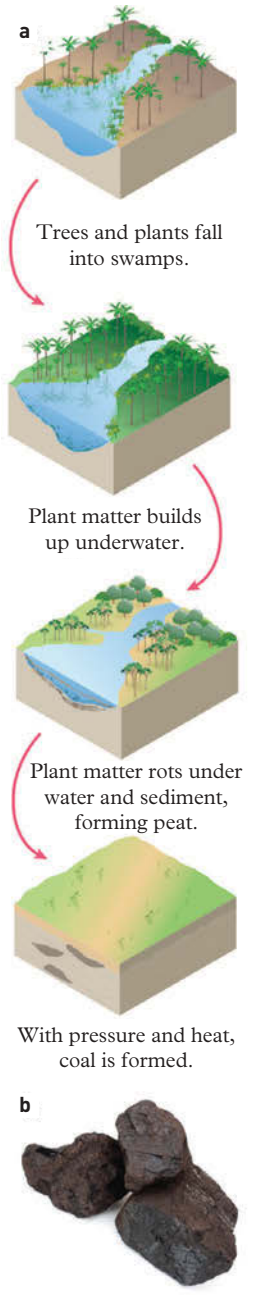


Figure 1a Formation of fossil fuels; **b** a piece of brown coal

We have all heard of the dinosaurs, and the large forests that once covered the Earth. The trees became fossil fuels over millions of years, which we now know as coal, oil and gas. They are called non-renewable resources.

Coal and other fossil fuels

Most of the energy used to produce electricity in Australia comes from coal. The energy stored in the coal is converted into electrical energy in a power station. In Victoria, most electricity is generated by power stations in the Latrobe Valley using brown coal. Large black coal resources are found near Sydney and in central and eastern Queensland. Coal is mined either in open-cut mines if it is close to the surface or in underground mines.

To produce and provide electricity to homes and businesses, we use a 'big circuit'. This circuit begins with the generators at a power station. Electrical energy is transported from the power station to homes, businesses and factories by conducting wires via transmission and distribution lines.



Figure 2 Mt Piper Power Station is a coal-fired power station in New South Wales.

The formation of fossil fuels

Fossil fuels were formed about 300 million years ago during the Carboniferous period, which was before the time of the dinosaurs. **Coal** is formed from the remains of trees and other plants that grew in tropical swamps.



Figure 3 An artist's impression of a tropical swamp in the Carboniferous period

When the trees and other plants died, they fell into the swamps. Because they were underwater where there was not much oxygen, the dead plants could not rot completely. The partly rotted plant material gradually built up, forming a layer of peat.

Over time, the layers of peat built up and then rocks formed on top of them. The pressure from the rocks on top and the heat from the Earth's crust underneath caused chemical reactions that gradually changed the peat into coal.

When coal is burnt, the chemical energy originally stored in the plants is released.

INVESTIGATION **8.4A:** What if a muffin was mined in different ways? Go to your obook.

INVESTIGATION **8.4B:** What if a metal was obtained from a mineral? Go to page 371.

Uranium

Uranium is the most common radioactive element on Earth, and Australia has the world's largest supply. Uranium is a non-renewable resource and Australia's supply is expected to last 140 years. Uranium gives out energy, called radiation, as it splits into other elements. Many of these other elements are also radioactive. This splitting process continues for a long time until a stable element is reached.



Figure 4 A nuclear power station

The energy from the splitting up of uranium heats water, turning it into steam. The steam drives turbines, which drive generators, just like in a conventional coal-fired power station. Unlike coal-fired power, nuclear power produces hardly any carbon dioxide emissions; however, it does produce radioactive waste that takes a long time to become safe or stable. Too much exposure to radiation can be harmful for humans.

Metal ores

Most of the human-made objects we use every day are made from materials that come from the Earth. The process of extracting useful minerals from the Earth is known as mining. Minerals are tiny grains or crystals that are the building blocks of rocks. Only a few minerals are found in a pure state, such as gold; mostly they are combined with other substances and need to be purified before they can be used.

Aluminium, for example, is not found as solid sheets in the ground. It is part of the ore called bauxite, which is made of aluminium, oxygen and iron. **Ores** are materials that contain a lot of a useful minerals mixed in with other substances. Australia is rich in metal ore deposits and many mines have been in operation for a long time.

How a mineral is mined depends on the location of the ore body. If the ore is on or close to the surface, open-cut mining is used (see Figure 6). If the ore body is deeper, underground mining is used and shafts are cut down into the ground to reach the ore. This attempts to protect the environment above but can be expensive and sometimes dangerous.

fossil fuel
a non-renewable energy source formed from plant and animal matter

coal
a fossil fuel formed from the remains of trees and plants that grew about 300 million years ago

ore
a mineral containing a large amount of useful metal



Figure 5 Bauxite ore contains aluminium.



Figure 6 Australia's single largest deposit of bauxite is at Weipa in northern Queensland, an open-cut mine.

Check your learning 8.4

Recall and explain

1 **Describe** fossil fuels. Give three examples.
2 **Describe** how coal is formed.
3 **Explain** what the term 'radioactive' means.
4 **Explain** why Australia mines metal ores.

Apply and analyse

5 **Compare** a nuclear power station and a coal-fired power station.
6 **Distinguish** between a mineral and an ore.

Evaluate and create

7 **Discuss** why you think Australia has not turned to nuclear power yet.

Skills builder: Planning investigations

8 Abby wants to observe how long it takes for trees to turn to coal.

Identify the problem with this idea for an investigation. (THINK: Is this problem testable?)

8.5 Soil is one of our most valuable resources

In this topic you will learn that:

- soil is a resource that provides essential nutrients for plants.

Lots of things come from our soil, including humans. If we could take out all the water from our bodies, most of what's left has come from the soil via the food we've eaten. And where do we end up when we die? Even if you are cremated, the carbon dioxide gas released is taken up by plants, which release it into the soil when they die.

Soil for life

Good gardeners know what makes good soil, and they add different things to the soil to improve it. They might add compost or animal manure to the soil to improve its organic content. They might add fertiliser, wetting agents or chemicals to change the soil structure.



Figure 1 Soil is a valuable resource.



Figure 2 Crops do best in soils that are carefully maintained.



Figure 3 Sand is one of the materials in concrete mix.

Most people think of soil as dirt, but good soil contains everything plants need to stay alive and grow. Without plants, many of our food sources would not exist. Pick up some soil – you will be holding your life in your hands.

Ingredients of soil

humus
decomposed plants and animals

Soils are complex mixtures of several materials, including sand, silt, clay and **humus** (decomposed plants and animals), as well as various minerals that plants need for healthy growth. Soils are formed when weather breaks down rocks over extremely long periods of time. Sand, silt and clay are all valuable natural resources because they can be mixed for use in construction.

Gardeners also need to monitor the tiny organisms that live in the soil. Many organisms, such as worms, help keep the soil healthy.



Figure 4 Worms break down organic matter. This helps to increase the amount of air and water in the soil.

INVESTIGATION

8.5: What if different soils were exposed to water?
Go to your obook.

Water-loving soils

Many Australians are frustrated by soils that don't let water soak in. How well a soil holds water plays a big part in how well plants will grow in that soil. Water drains easily through sandy soils, but sandy soils dry out easily. Heavy clay soils drain slowly; however, if the water can't run off, the clay becomes waterlogged and muddy.



Figure 5 Planting trees helps prevent further soil erosion.

Managing soils

Early Europeans arriving in Australia used the land in very different ways from Aboriginal and Torres Strait Islander peoples. The Europeans cleared the forests and had large numbers of sheep and cattle grazing the grasslands. This meant there were few grasses and plants to absorb the rain. As a result, water stored underground (the water table) rose, bringing salt closer to the surface. In addition, much topsoil was compacted by animal hooves. Land clearing and grazing have caused significant erosion. Thankfully, many farmers now practise sustainable agriculture, and land care groups help manage **land degradation**.

land degradation
the process of using up or removing the resources of land (such as water, topsoil, plants)



Figure 6 Healthy soil grows healthy plants.



Figure 7 Additives are used to improve soil.



Figure 8 Many plants and trees cannot survive in soils that are high in salt.



Check your learning 8.5

Recall and explain

1 **Identify** the basic components of soil.
2 **Describe** how soils are formed.

Apply and analyse

3 Consider how your life would be affected if there was no soil.
4 **Propose** four things that good gardeners might do to improve their soil.
5 Should a good soil drain water quickly or slowly? **Explain** your answer.

Skills builder: Conducting investigations

6 Suggest a logical procedure for collecting a sample of soil to test in the lab. Write a step-by-step procedure.
(THINK: What equipment would you need? Be specific about quantities.)

8.6 Our planet depends on careful management of resources

In this topic you will learn that:

- our supply of non-renewable resources is limited
- strategies to conserve our resources include reducing consumption and recycling.



Figure 1 'Reduce, reuse, recycle' is used as a slogan for conserving the Earth's resources.

We take many of our resources for granted, only thinking of them when they are in short supply. There are some people – scientists, engineers and others – who are very aware of the shortage of resources, and their jobs involve making the most of what is left. The key questions we all need to ask are: do we have enough resources for our future, and what impact is our resource use having on the planet?

Reduce, reuse, recycle

Non-renewable resources, such as fossil fuels and metal ores, need to be managed carefully so that our supply does not run out. We are also now aware of the impact of burning fossil fuels on **climate change**. Carbon emissions from burning fossil fuels can trap heat in the atmosphere, contributing to global warming.

To manage our supply of these resources and their impact on the planet, we need to reduce, reuse and recycle. **Recycling** is an important strategy for managing the supply and impact of fossil fuels. When we recycle, we convert rubbish into something that can be used again. For example, recycling just one plastic bottle can save enough energy to power a laptop for 25 minutes.

climate change
the change in global climate patterns, including temperature, over time

recycling
the process of turning waste into new materials

emission
the production and release of something (such as gas)

low-emissions vehicle
a car or bus that releases very little exhaust gases, including carbon dioxide

hybrid
a car that uses a mix of petrol and electricity

The problem with plastic

Plastic is often made from non-renewable sources such as oil. The plastic rubbish we throw away does not break down like food scraps. Instead, it ends up in landfill or floating in the ocean where it can have a damaging impact. For example, wildlife might confuse the rubbish for food or get tangled in, or injured by, the pollution.

So how do we manage this resource? By reducing, reusing and recycling plastic, we can reduce landfill and conserve fossil fuels.

Table 1 Reduce, reuse and recycle plastic

Reduce	Buy products that do not have plastic packaging and use alternatives to plastic (e.g. reusable bags or metal straws). You can also choose alternative plastic products, such as packaging made from natural, biodegradable materials.
Reuse	Reuse plastics such as containers for storage, or refill reusable drink bottles rather than buying one every time you are thirsty.
Recycle	Avoid putting plastic in the bin. Recycle your plastic so that it can be made into something else. Not all plastics can be recycled in the same way, so if in doubt – look it up.

Cars of the future

In Australia, **emissions** from cars are a major contributor to greenhouse gases. Most car companies have designed one or more **low-emissions vehicles** (LEVs). These cars have been available for the past few years and include hybrids, as well as very efficient petrol and diesel models. Cars with efficient engines use very little fuel. **Hybrids** use a mix of petrol and electricity.

The electric motor works with the petrol engine to reduce fuel consumption and emissions, but it does not eliminate them. Some cars, such as the Mitsubishi i-MiEV, are completely electric.

New types of batteries have made electric vehicles a reality. Although these cars can only run a certain distance before they need to recharge, battery life is improving all the time.



Figure 2 We need to protect our planet's ecosystems from human pollution.



Figure 3 The Mitsubishi i-MiEV, Australia's first all-electric car



Figure 4 Electric cars can be charged using a household power point.

Case study: Electricity of the future

BlueGen fuel cell units for houses are about the size of a dishwasher. They can generate electricity at up to three times the efficiency of current electricity systems. They significantly reduce greenhouse gas emissions and cut household energy bills. This is because they burn natural gas in an efficient closed system that collects both electricity and heat for use in the home. Each unit can produce up to 17 000 kilowatt hours of electricity per year. This is more than double the normal amount of electricity used in an average Australian home. The excess electricity generated by BlueGen can then be exported back to the electricity grid.



Figure 5 A BlueGen fuel cell unit

Check your learning 8.6

Recall and explain

1 **Explain** why we need to manage non-renewable resources.
2 **Identify** two reasons why we need to reduce our plastic usage.
3 **Explain** why BlueGen fuel cells are more efficient than other gas-burning devices.

Apply and analyse

4 **Apply** the 'reduce, reuse, recycle' approach to come up with your own strategies to manage the use of a fossil fuel.
5 **Propose** three more ways you could reduce or reuse plastic.

Evaluate and create

6 **Examine** your local area. This might be within 10 kilometres of your home, or further if necessary – you or your teacher will choose the distance. List all the natural resources you can locate in this area. **Identify** what each is used for. Present your findings on a large map in the classroom where every student can contribute their research.

Skills builder: Communicating

7 Imagine that you need to convince a group of people to use your strategies from question 4 to reduce and reuse plastic. Choose a text type to communicate your ideas and persuade people to try them. (THINK: What format do you think people would find appealing or engaging? How will you make your key points clear?)

8.7 People have different views about resources

In this topic you will learn that:

> the decision to use different resources can be influenced by different viewpoints that may be personal, political, environmental or financial.

In recent times, the use of coal in Australia has been hotly debated. Students around the world participated in climate strikes to protest the use of fossil fuels and raise awareness for climate change.

But there are a number of factors that should be considered when deciding how we use resources. Australia's economy receives a significant income from mining companies and the export of coal and minerals to other countries. Some argue that getting rid of mining in Australia would leave many people out of work. Meanwhile, others argue that these jobs could move into the renewable energy sector.

The government must weigh up the values and interests of different stakeholders. Table 1 provides some questions that might be considered when making decisions about coal mining in Australia.

Table 1 Considerations for coal mining in Australia

Environmental impact	• How does mining coal in Australia impact on the local landscape, habitats or wildlife? • Can mining companies rehabilitate the land they have mined? • How does mining coal contribute to climate change?
Financial impact	• How many people rely on coal for jobs? • How much tax do coal companies pay to the government, that they can spend on other things? • Would Australians need to pay more or less if a different source of energy was used?
Alternative resources	• Is there another resource that could support Australian energy requirements? • Is there another resource that would reduce our impact on the environment?



Figu The use of coal in Austra tly debated at present.

Why do people have different viewpoints?

When deciding what resources to use, individuals or groups may have different interests or values that inform their decision-making. These views come from a complex combination of factors, including education, where people live, quality of life, political beliefs and if people have any financial interest in the use of these resources.

For example, someone who is wealthy might be happy to pay more for renewable energy because they can afford it. Someone who works at a coal mine might prefer that Australia continues to use coal-powered energy because it will help them keep their job. Or someone who is environmentally conscious might value the use of renewable resources because they are concerned about the environmental damage caused by burning fossil fuels. Ultimately, our opinions are often influenced by our own interests.

What is your view?

The New Ecological Paradigm (NEP) scale was developed by researchers in the United States. It is a set of 15 statements designed to assess people's views on environmental issues, such as the use of renewable resources.

The NEP is based on the concept that people can have a human-centred world view (focused on personal or human issues) or an earth-centred world view (focused on sustainability and environmental impact).

To complete the test, you need to answer whether you agree or disagree with each statement on a scale of 1 to 5 (1 for strongly disagree, and 5 for strongly agree):

1 We are approaching the limit of the number of people the Earth can support.
2 Humans have the right to modify the natural environment to suit their needs.

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'Entire ecosystems are collapsing. We are at the beginning of a mass extinction and all you can talk about is money and fairytales of eternal economic growth. How dare you.'

– Greta Thunberg, environmental activist



'For the sake of our children and our future, we must do more to combat climate change.'

– Barack Obama, politician



'It is coal that has ensured for over a hundred years that Australia has enjoyed an energy competitive advantage that has delivered propsperity to Australian businesses.'

– Scott Morrision, politician

Figure 2 Three people whose views would influence their stance on resources

3 When humans interfere with nature it often produces disastrous consequences.
4 Human ingenuity will ensure that we do not make the Earth unliveable.
5 Humans are seriously abusing the environment.
6 The Earth has plenty of natural resources if we just learn how to develop them.
7 Plants and animals have as much right as humans to exist.
8 The balance of nature is strong enough to cope with the impacts of modern industrial nations.
9 Despite our special abilities, humans are still subject to the laws of nature.
10 The so-called 'ecological crisis' facing humankind has been greatly exaggerated.
11 The Earth is like a spaceship with very limited room and resources.
12 Humans were meant to rule over the rest of nature.
13 The balance of nature is very delicate and easily upset.
14 Humans will eventually learn enough about how nature works to be able to control it.
15 If things continue on their present course, we will soon experience a major ecological catastrophe.

Source: Riley Dunlap et al. (2000). Measuring endorsement of the new ecological paradigm: A revised NEP scale. *Journal of Social Issues*, 56 (3), 425–442.

Check your learning 8.7

Recall and explain

1 **Identify** two factors that may influence a person's opinion on using non-renewable or renewable resources.
2 **Identify** one reason to support the continued use of coal in Australia and one reason against it.

Apply and analyse

3 **Outline** the considerations that the government might take into account when weighing up the decision to continue coal mining in Australia.

Evaluate and create

4 Consider the quotes from different people in Figure 2. Based on their views, how do you think they are likely to impact on their reaction to the below scenarios. **Justify** your response.
   a Banning the use of coal
   b Reducing the cost of biofuels to power cars
5 Complete the NEP test. If you agree with the even statements, researchers would describe you as having a human-centred world view. If you agree with the odd numbered statements, researchers would describe you as having an Earth-centred world view.
6 **Reflect** on your world view based on the NEP scale. How do you think it compares with the rest of Australia?

Skills builder: Problem solving

7 **Evaluate** the following statement from the Australian Minerals Council: 'Mining companies contribute to local schools, medical services, sporting clubs and charities in communities around Australia.' (THINK: What influences their opinion?)

REVIEW

Multiple choice

1 Which of the following is considered a non-renewable resource?
- **A** Wind power
- **B** Solar power
- **C** Nuclear power
- **D** Wave power

2 Which of the following is considered a renewable resource?
- **A** Metal ore
- **B** Fossil fuel
- **C** Biofuel
- **D** Nuclear power

3 Tidal power is obtained from the:
- **A** biosphere
- **B** hydrosphere
- **C** lithosphere
- **D** atmosphere.

Recall and explain

4 **Explain** what renewable and non-renewable energy sources are, giving an example of each.

5 **Recall** why non-renewable resources are also called long-term renewable resources.

6 **Classify** the following resources as renewable or non-renewable.
- **a** Wind
- **b** Biofuel
- **c** Coal
- **d** Wave power
- **e** Natural gas

7 Coal is a fossil fuel. **Outline** how it would have been formed.

8 Metal ores can be extracted by mining. **Identify** one advantage and one disadvantage for doing this.

9 **Describe** three different uses of energy.

10 **Describe** a generator.

11 **Recall** a definition for the term 'geothermal energy'.

12 **Recall** the advantages and disadvantages of using uranium as an energy resource.

13 For each of the following spheres, **identify** one way energy can be extracted.
- **a** Hydrosphere
- **b** Lithosphere
- **c** Atmosphere
- **d** Biosphere



Figure 1 Geothermal energy in action

Apply and analyse

14 **Propose** one reason why it is important for soil to be 'water-loving'.

15 **Distinguish** between minerals and ores.

16 How does clearing plants from soil cause salt to come to the surface? Why is this a problem?

17 Table 1 shows the percentage of energy contributed to Australia's total energy consumption in 2017.

Table 1 Australia's total energy consumption

Type of energy	% of Australian energy in 2017
Oil	38.7
Coal	29.9
Gas	25.2
Renewables	6.20

- **a** **Construct** an appropriate graph to display this data.
- **b** Interpret this graph to **describe** how much oil, coal, gas and renewable energy we use in Australia.

18 **Explain** why oil and gas are described as fossil fuels.

19 If coal is so widely used for generating electricity, **outline** why some people are concerned about building new coal-fired power stations.

20 **Analyse** Figure 2, which shows how much energy of a state's total energy consumption comes from coal, oil, gas or renewables.
- **a** **Identify** which state uses the highest percentage of renewables.
- **b** **Identify** which state uses the lowest percentage of renewables.
- **c** **Describe** the energy mix used by New South Wales.

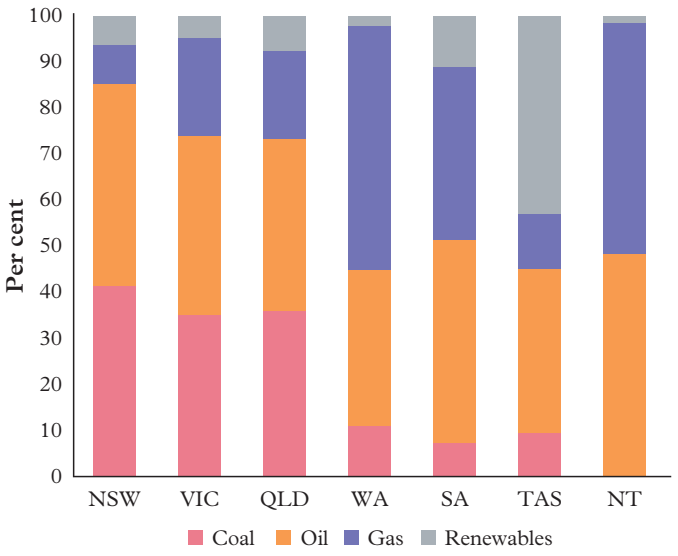


Figure 2 A state's total energy consumption

21 What advantages and disadvantages do electric vehicles have over petrol-driven cars?

22 What is wind farming? Are there any disadvantages to this method of energy production?

Evaluate and create

23 Is a hybrid car a low-emissions vehicle or a zero-emissions vehicle? **Explain** your answer.

24 A mining company would like to drill near a reef to extract crude oil. **Identify** possible advantages and disadvantages of this idea from the perspective of:

- **a** an environmental activist
- **b** a mining engineer.

25 Produce an A4 fact sheet with a diagram of your own electricity company (give it a name), describing how electricity is produced at your power station. **Justify** your choices.

26 Write a letter to the Federal Minister for Resources, Energy and Tourism, suggesting changes you would like to see happen in Australia. In your letter, include evidence that you know the current sources being used and that you have an understanding of the advantages and disadvantages of all options. You might like to prepare a renewable energy plan for Australia, and **explain** how your plan will be more sustainable than current uses of our country's energy sources.

27 If coal is so widely used for generating electricity, why are some people concerned about building new coal-fired power stations? **Evaluate** arguments for and against.

Critical thinking

28 Passenger cars, like those most people drive, are responsible for a significant amount of the population's energy consumption. Should people consider walking, cycling or taking public transport to reduce their energy consumption? What issues might they consider?



Figure 3 Should people consider walking to work?

29 Is soil a renewable or non-renewable resource? **Justify** your response.

30 What factors do you think are important when considering the use of a resource? Would others agree with you? Suggest a list of four key criteria that people could use to help them to decide whether or not to use a resource.

Going further

31 Coal is often described as a non-renewable fossil fuel. Is this description really accurate? **Explain** in relation to changes that are required for coal to form.

32 New Zealand produces a large amount of its energy from geothermal power. **Discuss** why this is so different from Australia.

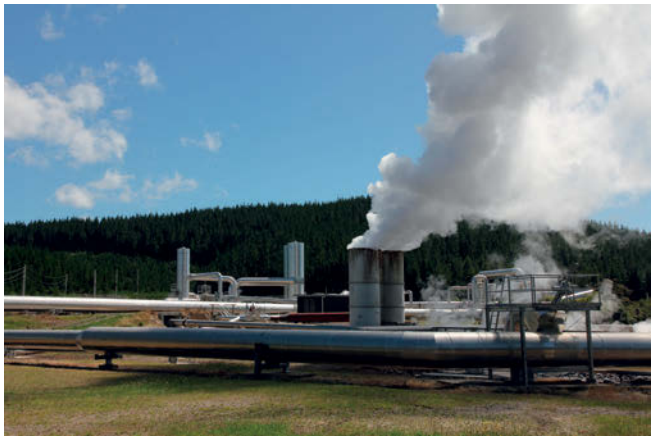


Figure 4 Wairakei Geothermal Power Plant in New Zealand

Research

33 Choose one of the following topics to research. Some questions have been included to get you started. An important part of your report must be to include references to the 'big picture', thinking about how your topic relates to the entire planet.

» A simple pencil

Examine a normal wooden pencil and determine all its component parts, including the lettering on the side. You may even want to dismantle the pencil and isolate each part. Next, think of all the steps needed to make the pencil. What are the components made of? Where would all the components have come from? What resources are needed to make the components? What resources are needed to assemble and finish the pencil in the factory? Present your research in a creative way.

» Clean coal

Is there such a thing as 'clean' coal? Why does coal need to be cleaned? Does clean coal exist now or is it still in the future? Is it costly? Find out about this technology and how it applies to Australia.

» Trapping carbon

The use of fossil fuels causes the release of carbon dioxide into the atmosphere. This has been linked to the gradual increase in global temperatures. Many countries are now finding ways to trap the carbon dioxide and store it in a less destructive way. How are Australia and other countries encouraging industry to use fewer fossil fuels? Describe one way that carbon can be trapped and stored. Which countries are using this method of trapping carbon?



Figure 5 How is a lead pencil made?

Reflect

Now that you've completed this chapter, reflect on your ability to do the following:

	I can do this.	I can't do this yet.
Classify a range of the Earth's resources as renewable or non-renewable.	☐	☐ Go to page 122–123.
Outline features of some non-renewable resources, including metal ores and fossil fuels.	☐	☐ Go to page 130–131.
Describe uses of a variety of natural and made resources extracted from the biosphere, atmosphere, lithosphere and hydrosphere.	☐	☐ Go to page 126–129.
Investigate some strategies used by people to conserve and manage non-renewable resources, e.g. recycling and the alternative use of natural and made resources.	☐	☐ Go to page 134–135.
Discuss different viewpoints people may use to weight criteria in making decisions about the use of a major non-renewable resource found in Australia.	☐	☐ Go to page 136–137.
Outline the choices that need to be made when considering whether to use scientific and technological advances to obtain a resource from Earth's spheres.	☐	☐ Go to page 136–137.

Source: NSW Science Years 7-10 Syllabus © NSW Education Standards Authority for and on behalf of the Crown in right of the State of New South Wales, 2018.

WATER

How do we use water as a resource?

9

Have you ever wondered...

- Why do people think water is so valuable?
- Why do we have droughts?
- Do we drink the same water we flush down the toilet?

SCIENCE UNDERSTANDING

In this chapter you will learn how to:

- identify that water is an important resource that cycles through the environment
- explain the water cycle in terms of the physical processes involved
- demonstrate how scientific knowledge of the water cycle has influenced the development of household, industrial and agricultural water management practices
- research how Aboriginal and Torres Strait Islander peoples' knowledge is being used in decisions to care for Country and Place, e.g. terrestrial and aquatic resource management.

Source: NSW Science Years 7–10 Syllabus © NSW Education Standards Authority for and on behalf of the Crown in right of the State of New South Wales, 2018.

Check your Student obook assess for these digital resources and more:

QuizletLive
Compete in teams to test your knowledge.

Assess quiz
Before you start this chapter, assess your science skills.

Check your Teacher obook assess for these digital resources and more:

QuizletLive
Launch a quiz for your students on key concepts in this chapter.

9.1 Water cycles through the environment

In this topic you will learn that:

- the water cycle describes the movement of water through the environment
- processes in the water cycle include evaporation, condensation, precipitation, infiltration (groundwater) and transpiration.

Water is an important resource. Like many other resources, there is only a certain amount of water on Earth and this amount does not change. Even when water evaporates and becomes a gas, it has not stopped existing – it is just invisible to the eye. Water moves constantly between the three major states – solid, liquid and gas – in a process called the water cycle.

Evaporation in the water cycle

In the **water cycle**, heat energy from the Sun evaporates water from lakes, rivers, oceans and the land. Most of Earth's surface is covered by the oceans and seas, so most of the **water vapour** (gas) in the air comes from them. When water **evaporates**, it leaves behind anything dissolved in it (like crystallisation, when you separate mixtures).

Condensation in the water cycle

As the water vapour rises, it is cooled by the air. Eventually, the air becomes saturated (filled) with water vapour and cannot hold any more. This is called **condensation**. When this happens, some of the water vapour will change into tiny water droplets (liquid). This is how clouds form.

Precipitation in the water cycle

The tiny, warm water droplets rise in the atmosphere and form clouds. The higher the clouds go, the cooler the air becomes. The droplets then combine to form larger droplets, which can fall as rain, hail or snow (different forms of **precipitation**). In this way, the same water that evaporated is returned to the land,

condensation
the change of state from a gas to a liquid; occurs when a gas cools down

water cycle
the cycle of constant evaporation and precipitation that occurs in nature

water vapour
water in the gaseous state

evaporate
to change in state from liquid to gas; also a separation technique used to separate dissolved solids from water

precipitation
the process in which water vapour in the upper atmosphere becomes liquid water in the form of rain, snow or sleet and falls to the ground

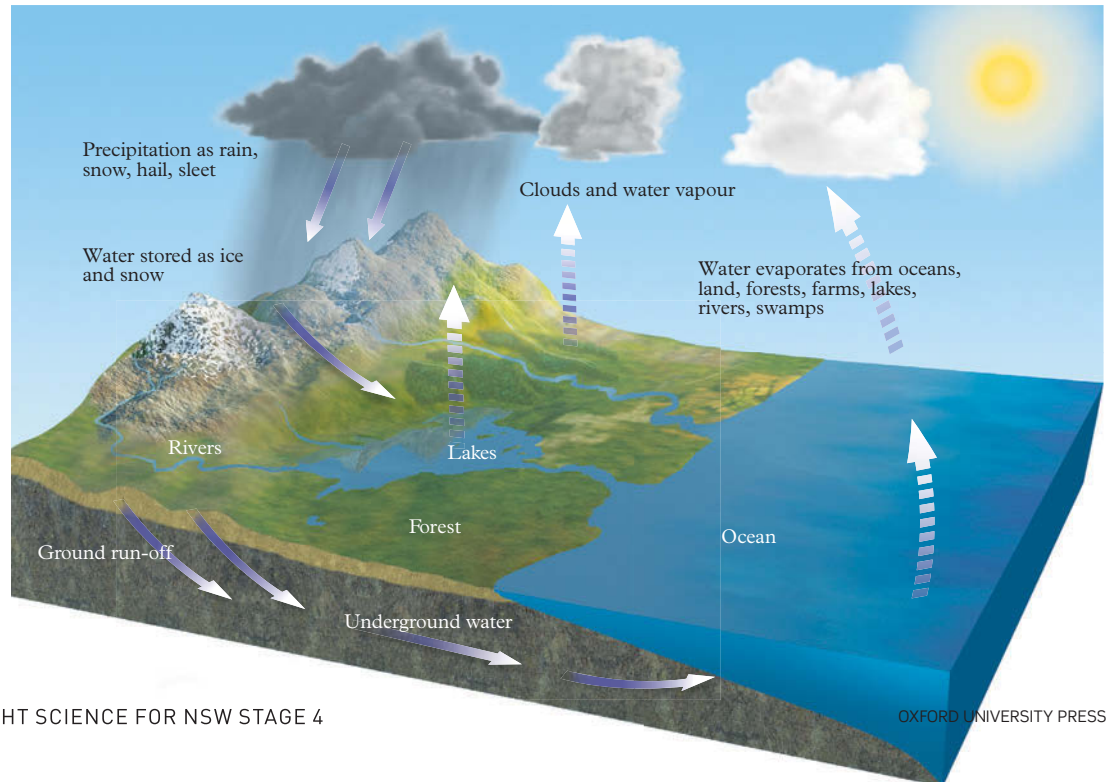


Figure 1 The water cycle

INVESTIGATION
9.1: What if the temperature was hotter in the water cycle? Go to page **372**.



Figure 2 Rain, hail and snow are all types of precipitation.

flowing through rivers until it finally returns to the oceans.

Sometimes the water droplets in the clouds are moved by the wind to the mountains where the air is very cold. This causes the liquid water droplets to freeze into snow and ice.

Infiltration

Once the liquid water is on the Earth's surface, it can infiltrate (or soak into) the ground and form **groundwater**. Deep underground there are rivers and lakes that store water. To get there, the rainwater must soak in through and around the small rocks and pebbles that make up the earth. Eventually, it reaches solid rock and forms small pools of water called aquifers.

Transpiration

Animals and plants are also part of the water cycle. Animals and humans excrete (get rid of) water as waste or through evaporation (sweat). Plants take in water from the soil through their roots. This water travels through the plant to the leaves. Once the water has reached the leaves, it can evaporate. This evaporation of water is called **transpiration** (see chapter 12). The water vapour from both plants and animals also goes into the water cycle.

Water is constantly on the move. It changes from rain to water vapour to clouds to rain again, over and over. By constantly changing state, water never disappears – it is just recycled through the environment.

transpiration
the process by which plants take up water from the soil through their roots and up into their leaves

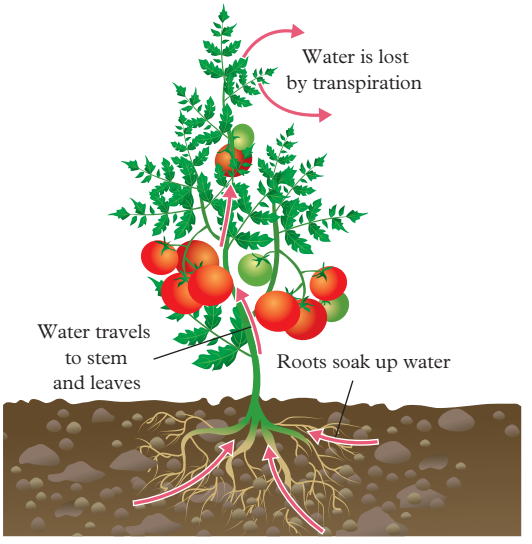


Figure 3 Transpiration in a plant

groundwater
water found beneath the Earth's surface

Interactive
The water cycle

Check your learning 9.1

Recall and explain

1 **Explain** why the movement of water around the environment is called a cycle.
2 **Identify** examples from the water cycle of:
   a frozen water
   b water gas
   c liquid water.
3 **Explain** the process of transpiration through a plant.

Evaluate and create

4 True or false? The same water you drank today could have been drunk by a dinosaur millions of years ago. **Explain** your answer.

Skills builder: Communicating

5 **Create** a simple labelled diagram of the water cycle.
(THINK: How could this diagram help people to understand the water cycle?)

9.2 Factors in nature affect the water cycle

In this topic you will learn that:

- the water cycle can be influenced by changes in temperature and natural disasters.

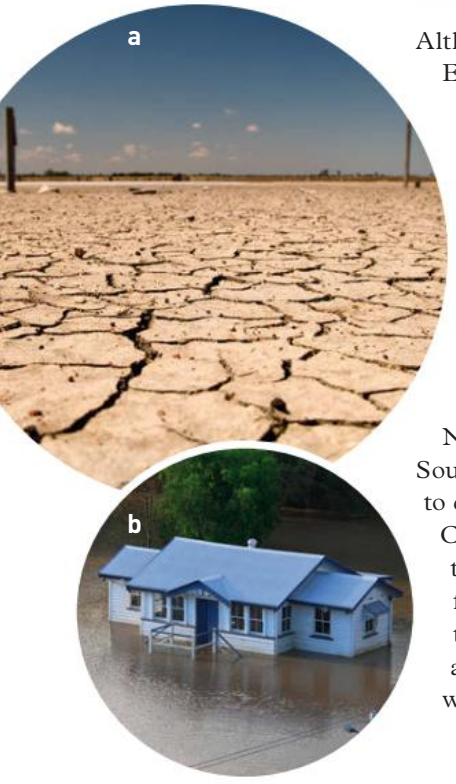


Figure 1 Areas in Australia affected by **a** drought and **b** flood

Although water has been cycling since the Earth was first formed, this cycle can be affected by many things. Changes in temperature, the direction of the wind and the number of plants all affect how fast water evaporates and therefore the amount of water vapour in the air.

El Niño and its effect on Australia

You have probably heard of the El Niño effect. Fisherpeople in Peru, South America, originally used this term to describe the appearance, around Christmas, of a warm ocean current off the coast that brought heavy rain and floods. Nowadays, 'El Niño' describes the extensive warming of the central and eastern Pacific Ocean. Combined with this ocean warming are changes in the atmosphere that affect weather patterns across countries around the Pacific Ocean, including Australia. In Australia, El Niño events usually mean less rain will fall.

El Niño events occur approximately every 4–7 years and usually last for about 12–18 months. They are a natural part of the climate system and have been affecting Pacific countries for thousands of years.

Each El Niño event is unique in terms of how much the ocean temperature warms and how rainfall patterns change. El Niño events usually result in less rain across parts of eastern and northern Australia, particularly during winter, spring and early summer. Where and when this happens differs a lot from one event to another, even with similar changes and patterns in the Pacific Ocean. In 2002–03, a relatively weak El Niño event resulted in severe drought.

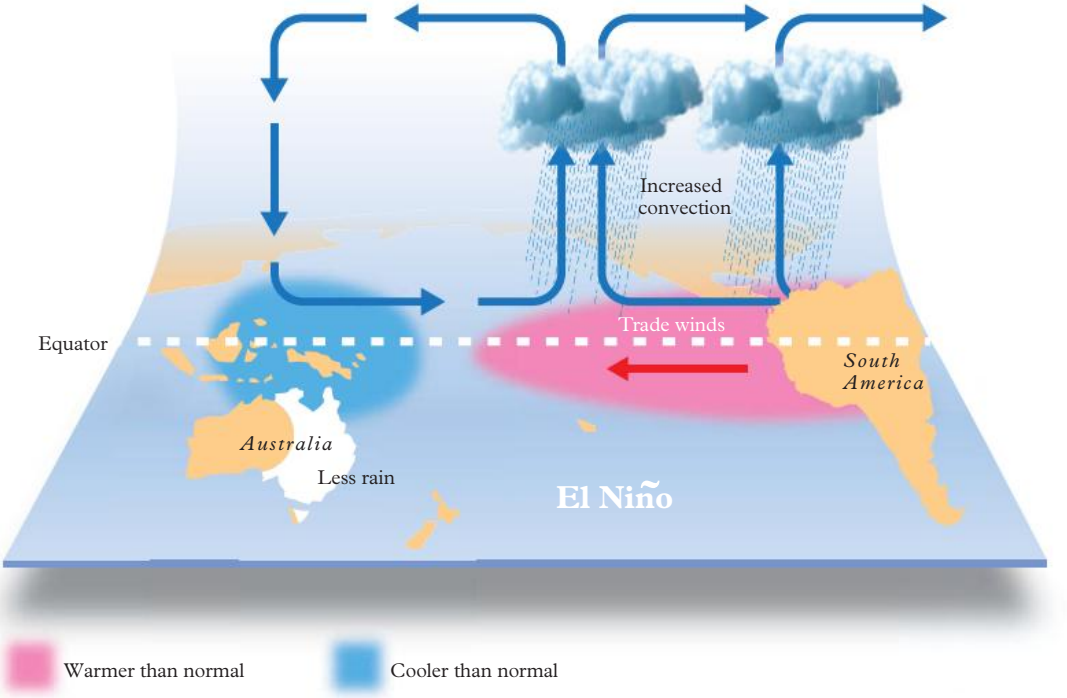


Figure 2 During an El Niño event, there is an increased chance of drier conditions in Australia because of the combined effects of ocean warming and changes in the atmosphere that affect weather patterns.

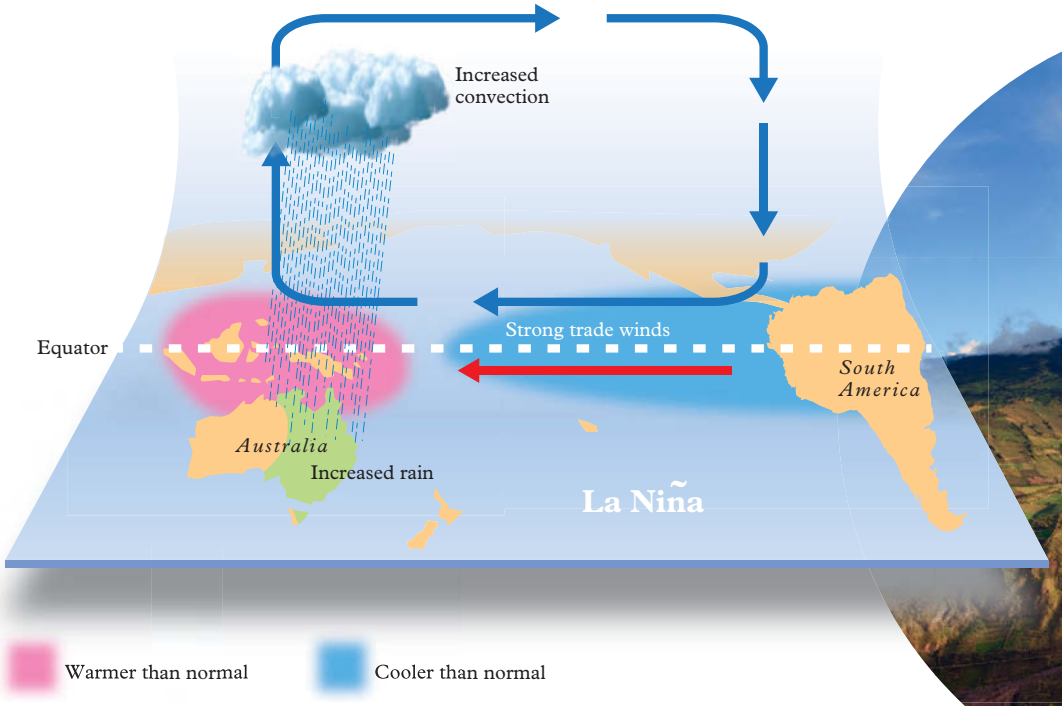


Figure 3 A La Niña event results in an increased chance of wetter conditions along the east coast of Australia because of ocean cooling and stronger winds.

La Niña

In 2010–11, a La Niña event caused widespread flooding, especially in Queensland and Victoria. The opposite of El Niño, La Niña occurs when the ocean current is cooler and the winds are stronger. This results in greater-than-usual amounts of rain falling along the east coast of Australia.

Volcanic eruptions

Volcanoes erupt regularly around the world every year. Occasionally there is a major eruption, like the 2011 Nabro eruption in Eritrea, Africa, which discharged large amounts of dust and particles into the air. The particles reflected the sunlight, preventing the Earth (and water) being heated. Less water evaporated, resulting in less water vapour condensing into precipitation (rain). Some countries therefore experienced a drier climate in the year after the eruption.



Figure 4 A volcano erupting

volcano
a vent or hole in the Earth where molten (melted) rock ash and other materials escape onto the surface

Check your learning 9.2

Recall and explain

1 **Describe** how El Niño affects Australia.

2 **Describe** how La Niña affects Australia.

Evaluate and create

3 **Investigate** if there are any erupting volcanoes in Australia.

4 **Construct** a flow chart of how volcanic dust particles blocking sunlight affect the water cycle. Include all parts of the water cycle.

Skills builder: Questioning and predicting

5 Examine Figure 1.

a Write three observations about each image. (THINK: What can you see? Be specific about what you observe, such as colour and texture.)

b Write one question about each image. (THINK: What would you like to know more about? Use 'How', 'Why', 'Where', 'What' or 'When' to start your question.)

c **Identify** the resources you might use to investigate this question.

9.3 Human management affects the water cycle

In this topic you will learn that:

- scientific understanding of the water cycle influences agriculture and industry
- humans have developed techniques to manage our water supply, including dams and distillation.



Figure 1 Water is used for the irrigation of crops.

Interactive
Overuse of water

Interactive
Map: Australia's rainfall

Resource
STEM activity: Help ... I'm stranded!

Water is used to grow the food we eat, to make the clothes we wear and to clean our homes and ourselves. All of this affects the water cycle.

Agriculture

Most of the water used by humans in Australia every year is needed for growing our food. Most of this is used for irrigation – the artificial watering of the Earth for agriculture. Often the water is sprayed onto crops to ensure they do not die in dry areas such the Murray River Basin.

Often the water used for irrigation is taken from the groundwater or from rivers or lakes. This reduces the amount of water flowing into rivers, which has an impact on the native plants downstream. It also washes dirt and fertilisers into the waterways. This affects the plants and animals that rely on the clean water to live.

Increased watering in some areas can also result in an increase in the amount of groundwater. Groundwater is often salty, so the salt comes to the surface with the water, making the soil too salty to grow food. Farmers often need to carefully manage water levels so that they balance the need to grow the food with the need to maintain the water cycle.

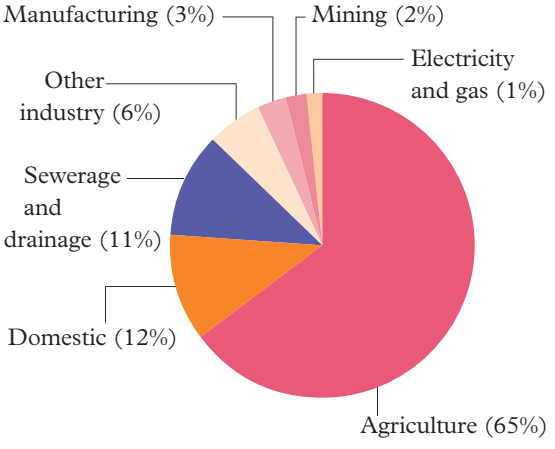


Figure 2 Water is used for many purposes across Australia.

Industry

One of the biggest impacts on the water cycle is the use of fossil fuels to produce electricity for factories. This burning of fossil fuels causes the production of carbon dioxide, which is a greenhouse gas. This means it can absorb heat, making the air around the Earth stay warm. The extra heat from high levels of carbon dioxide causes more water to evaporate and stay in the air as water vapour. This can lead to changes in the weather, including more rain in some areas and droughts in other areas. It is also contributing to the melting of the ice caps, causing even more water to re-enter the water cycle.

Dams

Australia is the world's driest continent. We store more water than any other country – more than 4 million litres of water per person! Australia requires such a large storage capacity to ensure a reliable water supply during periods of drought.

Large dams and reservoirs have been built to collect and store water. Two of the largest storage reservoirs in Australia are the Warragamba Dam in Sydney, which can store 2 million megalitres (2 million million litres), and the Thomson Dam in Victoria, which can store 1 million megalitres. Storing water in dams reduces the water flowing down rivers and into the ocean.

CHALLENGE

9.3: Can you reduce the evaporation of water in irrigation channels? Go to page **373**.

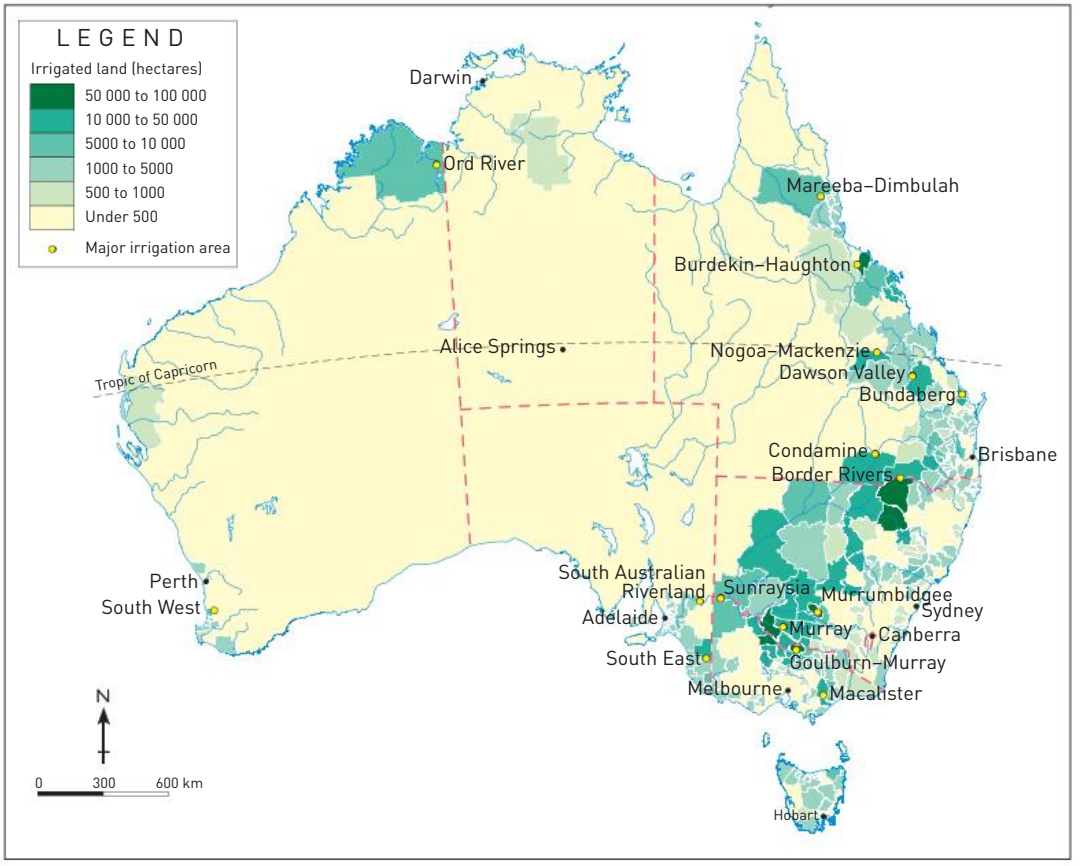


Figure 3 Agricultural irrigation of food accounts for 65% of the water used in Australia.



Figure 4 Industry has significantly contributed to the release of carbon dioxide and water vapour into the atmosphere.



Figure 5 The Warragamba Dam provides the drinking water for greater Sydney.

Distillation

Even though salt water is not suitable for drinking, in dry countries like Australia the idea of changing salty water into fresh water is very appealing.

One way to do this is by **distillation**. In this separation process, heat is used to evaporate water from the salt. The steam is collected and condensed into pure liquid water.

Distillation has been used for many years in **desalination plants** to produce fresh water from sea water, particularly in some Middle Eastern countries. However, it is very expensive and uses a great deal of energy. With improved technology, Australian state governments are building, or planning to build, desalination plants to increase the water supply.

desalination plant
a large facility set up to produce fresh water from salt water

distillation
a process using heat to evaporate water leaving behind a residue (e.g. salt)

Check your learning 9.3

Recall and explain

1 **Recall** how we use water for agriculture.
2 **Explain** how industry has impacted the water cycle by burning fossil fuels.

Apply and analyse

3 **Explain** why desalination uses a lot of energy.
4 **Identify** three ways you have used water in the last 24 hours.

Evaluate and create

5 **Construct** a diagram of the water cycle and highlight where in the cycle the water you use comes from.
6 **Investigate** where the water supplies you use come from.

Skills builder: Processing and analysing information

7 **Examine** the sector graph in Figure 3. (THINK: All the information you need to answer the following questions is included there.)
   a What percentage of Australia's water is used by manufacturing?
   b Compare Australia's domestic use of water with its agricultural use of water.

9.4 Water is a precious resource

In this topic you will learn that:

- a very small percentage of the Earth's water is drinkable
- Aboriginal and Torres Strait Islander peoples developed ways of managing water sustainably in Australia.

Approximately two-thirds of the Earth's surface is covered with water, yet in Australia we have very little fresh water. Of all the water on Earth, 97.5% is salt water – the remaining 2.5% is fresh water. Of the tiny percentage of fresh water in the world, most of it is locked either in ice caps and glaciers or in the soil. This leaves approximately 0.007% of the Earth's water available for drinking.

Sustainable water use by Aboriginal and Torres Strait Islander peoples

For thousands of years, Aboriginal and Torres Strait Islander peoples have managed water resources sustainably. But for many Indigenous nations, water is not just a resource: it is part of their culture.

Fish traps on the Barwon River in Brewarrina, also known as Baiame's Ngunnhu (pronounced 'By-ah-mee's noon-oo'), show the connection between caring for Country and Indigenous culture. These fish traps are made from an elaborate network of rocks placed in the river to catch fish as they swim upstream. The traps are not only used as a source of fish to eat, but they also slow the flow of water to keep a sustainable supply of fresh water for people. The local Ngemba people have a strong spiritual connection to the traps. According to stories passed down, the traps were built by the ancestral figure Baiame, who threw his net across the river, creating the shape of the traps. The traps are also an important meeting site for other nations, including the Morowari, Parrkinji and Kamilaroi people.

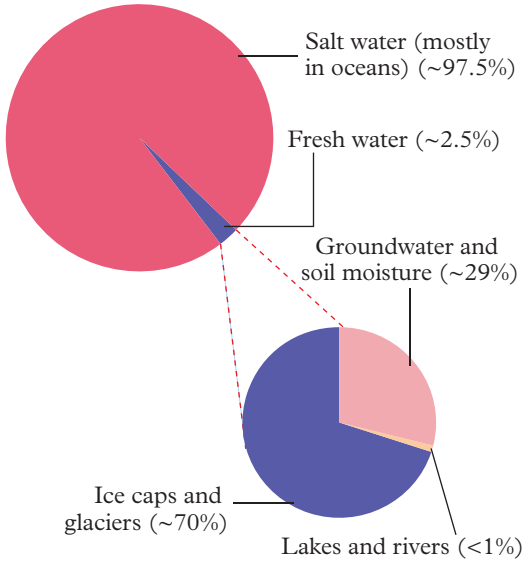


Figure 1 Only a very small percentage of water on the Earth is fresh and unfrozen.



Figure 2 Brewarrina fish traps, Baiame's Ngunnhu

The different water management practices of Aboriginal and Torres Strait Islander peoples across Australia show sophisticated understanding of the water cycle. For example, some groups used their understanding of groundwater to dig underground reservoirs that helped them to live in dry climates. Other groups filtered water and covered it to prevent it from evaporating or being contaminated.

Scientists are beginning to collaborate with Aboriginal and Torres Strait Islander peoples to learn more about traditional water management. By working together, governments and other groups can use their shared knowledge to make better decisions about water, how it is managed and how our actions may impact on the environment.



Figure 3 A rainwater tank is used to capture and store rainwater that can then be used to water the garden, flush toilets and even wash clothes.

Sustainable water use at home

Individuals can also manage water use more sustainably. To cope with our unpredictable weather, Australians are encouraged to think carefully when building new homes, businesses and even gardens.

Drought-tolerant plants are big sellers in plant nurseries all over Australia. Gone are the days when 'English' country gardens were practical options, with succulents and native species now the plants of choice. These native species need less water to survive, meaning people do not need to use as much water to keep their gardens alive. In some places, the government has restricted our use of water and the price of water is increasing.

Rainwater tanks are popping up in backyards all over the country, more water-saving shower heads are being used and the use of grey water systems is increasing.



Figure 4 Water-saving shower heads are used to reduce the amount of water we use when showering.

Check your learning 9.4

Recall and explain

1 **Recall** how much of the world's water is drinkable.

2 **Describe** one way that Aboriginal and Torres Strait Islander peoples used their understanding of the water cycle to manage water.

3 **Identify** two strategies that Australians could use to save water in their own homes.

Evaluate and create

4 **Investigate** how Aboriginal and Torres Strait Islander people's knowledge is being used in decisions to care for Country and Place. For example, you could investigate one specific project, such as the Snowy River Scheme, and describe how Aboriginal and Torres Strait Islander knowledge helped to make decisions.
Share your findings with your class as a poster or oral presentation.

Skills builder: Conducting investigations

5 **Assess** one of the secondary sources you used to answer question 4.

a Is the author of the source reliable? (THINK: Is the person who wrote it an expert? What makes them an expert?)

b When was the source created? (THINK: Is it the most up-to-date information available?)

c What would make it a more reliable source of information? (THINK: Does it provide enough detail? Was it easy to understand?)

REVIEW

Multiple choice

1 What term describes the process in the water cycle when a gas cools to become a liquid?
- **A** Condensation
- **B** Evaporation
- **C** Transpiration
- **D** Desalination

2 What percentage of the Earth's water resources is suitable for drinking?
- **A** 97.25%
- **B** 12%
- **C** 2.5%
- **D** 0.0007%

3 In what process does water fall and soak into the ground to become groundwater?
- **A** Filtration
- **B** Soaking
- **C** Infiltration
- **D** Desalination

Recall and explain

4 **Identify** three ways water is used as a resource.

5 **Recall** and **describe** three processes involved in the water cycle.

6 **Explain** transpiration.



Figure 1 Clouds forming in the troposphere

7 **Identify** what clouds are made of.

8 **Recall** where fresh water is stored on Earth.

9 **Explain** how the way we live affects the water cycle.

10 **Identify** what natural factors can affect the water cycle.

11 **Recall** one way you can save water at home.

12 **Outline** how Aboriginal and Torres Strait Islander knowledge could be used to manage our water resources.

Apply and analyse

13 In the United States, salt is spread over the footpaths in winter. **Explain** why this is done.



Figure 2 Road maintenance vehicle spreading salt on footpath

14 Working in a small group, **investigate** the advantages and disadvantages of desalination plants. Make a poster that lists the advantages and disadvantages of these plants.



Figure 3 The Perth desalination plant supplies nearly 17% of Perth's drinking water.

15 **Explain** why you should water the roots of a plant and not the leaves.

16 **Predict** how an El Niño event would affect your life.

17 In the eighteenth century, Captain James Cook embarked on several voyages to the Pacific Ocean to explore new lands, including Australia. Despite being surrounded by water, his crew was constantly at risk of dying of thirst. **Explain** this.

Evaluate and create

18 Create a model of the water cycle. What could you use to represent the three stages of water? Show how each stage is connected to the others.

19 Make a list of the different categories of water-saving devices currently available. If you could only choose three devices to install in your house, which three would you chose and why? Write a short description of each of the three water-saving devices you have chosen. Include an image for each one and indicate how it helps save water. What things does your family do to save water around your house?

20 As lack of water becomes a bigger national problem, more people will be required to work in the water industry, such as hydrologists, environmental scientists and environmental engineers. Choose one of these professions and investigate the following:

- **a** What work does this person do?
- **b** What subjects should be studied in school in order to enter into this career?

21 Much of the area around Queenstown, on the western coast of Tasmania, is now barren and lifeless (see Figure 4). **Investigate** what happened here to cause the devastation. **Explain** in detail why this land hasn't been rehabilitated and why the area will take many thousands of years to recover.

22 Certain plants can act as effective filters of rainwater. When it rains, some water ends up in the underground water table and can be pumped up for use elsewhere. **Investigate** plants as filters.

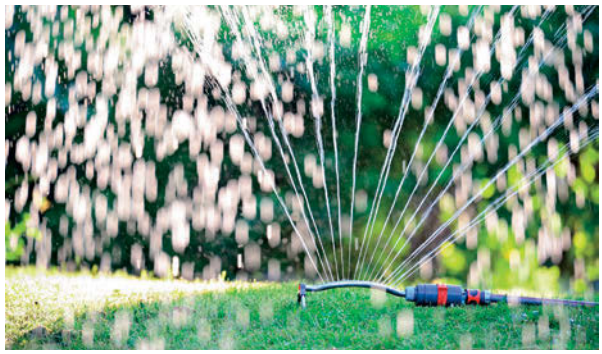


Figure 5 A sprinkler system watering garden

Critical thinking

23 Imagine that your neighbour waters their garden whenever they like for as long as they like. Is there a certain time of day when it is better to water plants? Are there restrictions in your area about when you can water the garden? Suggest three guidelines your neighbour should follow.

24 We use water for agriculture, industry, domestic use and more. Is one use of water more important than the others? **Discuss**.

Going further

25 **Discuss** the impact of climate change on the water cycle.

26 Imagine that you are on a research ship in the middle of the ocean. You have run out of fresh water, but you have a fully equipped science lab. Design an experiment that would allow you to turn the salt water of the ocean into drinkable water.



Figure 4 What happened in the Queenstown hills?

Research

27 Choose one of the following topics on which to conduct further research. A few guiding questions have been provided for you, but you should add more questions that you wish to investigate. Present your findings in a format that best fits the information you have found and understandings you have formed.

» Water-sensitive urban design

Australians are regularly encouraged to be 'water wise' when planting their gardens. What does it mean to be water wise? How is this linked to ecosystem benefits? Many people think this is the future of all urban landscapes. In terms of a water-sensitive urban design, would a faster or slower filtration flow rate be better? (Hint: Consider where the water might be going to.) Do all areas of Australia need to be reducing their garden's water requirements?

» Sewage treatment

Find out more about how your city treats its sewage. What is sewage? What is the difference between sewage and sewerage? Has sewage treatment in your city always been the same? Many countries drink water that was once sewage but has been treated. Do you think this is a good idea? How do your actions affect sewage and water quality? How can you make a difference to the water in your environment? Give a multimedia presentation to the class.

» Grey water at home

Find out more about grey water systems. What is grey water? Which water from the home can be re-used? How is grey water purified? Why don't more people install grey water systems in their homes? What is 'black water'? Where does black water go?

» Caring for country

Who are the traditional custodians of the land your home and school is on? Find out how Aboriginal and Torres Strait Islander people's knowledge is being used in decisions to care for country and place in your local area or elsewhere in New South Wales. How can water or aquatic environments such as lakes and coastlines be managed more sustainability with this knowledge?

Reflect

Now that you've completed this chapter, reflect on your ability to do the following:

	I can do this.	I can't do this yet.
Identify that water is an important resource that cycles through the environment.	☐	☐ Go to page 146–149.
Explain the water cycle in terms of the physical processes involved.	☐	☐ Go to page 142–145.
Demonstrate how scientific knowledge of the water cycle has influenced the development of household, industrial and agricultural water management practices.	☐	☐ Go to page 146–149.
Research how Aboriginal and Torres Strait Islander peoples' knowledge is being used in decisions to care for Country and Place.	☐	☐ Go to page 148–149.

Source: NSW Science Years 7–10 Syllabus © NSW Education Standards Authority for and on behalf of the Crown in right of the State of New South Wales, 2018. INVESTIGATION

CLASSIFICATION

Why do we need to classify living things?



10

Have you ever wondered...

- Is a 'liger' a lion or a tiger? Is a labradoodle a labrador or poodle?
- Should a penguin be called a bird if it can't fly?
- Why do we classify films into different ratings?

SCIENCE UNDERSTANDING

In this chapter you will learn how to:

- identify reasons for classifying living things
- classify a variety of living things based on similarities and differences in structural features
- use simple keys to identify a range of plants and animals
- identify some examples of groups of micro-organisms
- outline the structural features used to group living things, including plants, animals, fungi and bacteria
- explain how the features of some Australian plants and animals are adaptations for survival and reproduction in their environment.

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Check your Student obook assess for these digital resources and more:

QuizletLive
Compete in teams to test your knowledge.

Assess quiz
Before you start this chapter, assess your science skills.

Check your Teacher obook assess for these digital resources and more:

QuizletLive
Launch a quiz for your students on key concepts in this chapter.

10.1 Classification organises our world

In this topic you will learn that:

- classification is the process of grouping or organising things
- classification systems help scientists to communicate and understand the relationships between things based on their similarities or differences.

Classification involves grouping or organising things based on similarities or differences in their characteristics. For example, we can classify food into food groups such as vegetables and fruits. We can also classify movies into genres such as comedy or drama. There are many reasons why classification can be useful.

Classification helps us to organise information

Early humans first classified plants and animals to assist in their survival. They had to learn which plants were edible, which could help sick people and which were poisonous. Similarly, some animals could produce food, such as milk and eggs, while other animals might be dangerous. A new plant or animal discovered by humans was, and still is, studied and organised into a group. Each generation of scientists continues to improve how these groups are classified.

Classification helps scientists to communicate

Science is a collaborative field. Scientists will regularly communicate to share ideas and further their research.

Early scientists did not have modern technologies that would allow them to record and capture images of new plants or animals they discovered. Instead, they relied on hand-drawn pictures and written descriptions. This method of documenting new species led to challenges. Drawings and descriptions did not always show the subtle differences between species. For example, the South American greater rhea, the Australian emu and Southern cassowary all have obvious similarities (see Figure 1).

The word 'emu' is derived from an Arabic word for large birds. Portuguese-speaking South Americans refer to the greater rhea as an emu. Early Portuguese explorers to

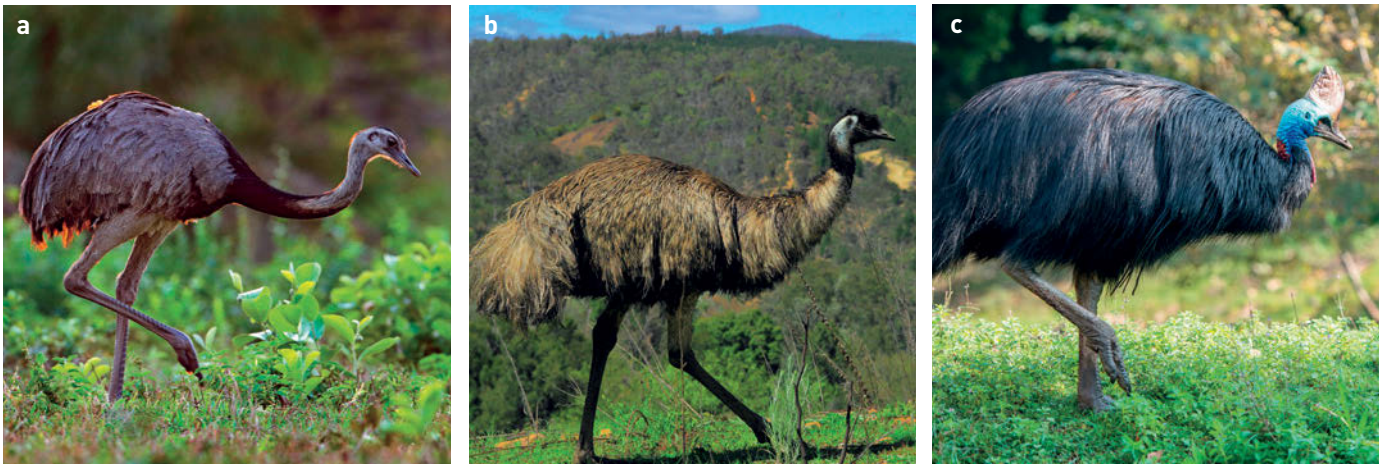


Figure 1 a The greater rhea (*Rhea Americana*), **b** the Australian emu (*Dromaius novaehollandiae*) and **c** the Southern cassowary (*Casuarius casuarius*)

CHALLENGE

10.1: Department store classification
Go to your obook.

Australia and Indonesia used the word 'emu' to first describe cassowaries. Then European explorers used the same word to describe the Australian emu. In short, three birds were all given the same name. To overcome this kind of confusion and assist classification, a system was developed by Swedish scientist Carolus Linnaeus (1707–1778) in which all species were given a unique scientific name. The name *Dromaius novaehollandiae* for the Australian emu means the same to scientists in every country around the world.

Finding new species

Small groups of scientists are trying to find undiscovered plants (new **species**) in Brazilian rainforests before they are destroyed by logging and farming. Often the scientists are supported by large pharmaceutical companies from other countries. Why would companies on the other side of the world be interested in saving plants and animals in the rainforest? One reason is that we may one day need these undiscovered organisms. Many of the medications we currently use come from organisms. The antibiotic penicillin was discovered from a type of mould, and aspirin comes from a substance in the bark of willow trees. The next painkiller could come from a small fungus in the rainforest or an insect that relies on the fungus for food.



Figure 2
Carolus Linnaeus

species
a group of organisms that look similar to one another and that can breed and produce fertile young



Figure 3 The rainforests of Brazil contain many undiscovered plant species.

Check your learning 10.1

Recall and explain

1 **Define** the term 'classification'.
2 **Describe** two other examples of classification in your daily life.
3 **Explain** two reasons why scientists classify organisms.

Apply and analyse

4 **Explain** the advantage of each species having a unique scientific name.

Evaluate and create

5 The earliest scientists did not have pens or paper. How would they have passed on the information they discovered? **Evaluate** how accurate it would have been.

Skills builder: Planning investigations

6 Gordon found a strange species of insect in his backyard, but he could not identify what it was. **Suggest** what equipment Gordon could use to record his observation so that he could ask an expert later. (THINK: What information would he need to record so that an expert could help him? What is the best way to capture this information?)

10.2 All living things have characteristics in common

In this topic you will learn that:

- living things (organisms) can be classified based on structural similarities and differences
- something that is dead used to have the characteristics of living organisms, whereas something that is non-living never had these characteristics.

Characteristics of living things

Before we can begin to classify living things, also called organisms, we must first understand what it means to be alive. It has taken many years of observation and discussion for scientists to develop eight characteristics that all living things – plants, animals and even micro-organisms such as bacteria – have in common. To remember all eight characteristics, just think: MR N GREWW.

M Living things can MOVE by themselves

Animal movements are easy to see. Picture a bird flying or a dolphin swimming. But do plants move? Look at the leaves on an indoor plant – they usually face the window (a source of light). Turn the plant around so that the leaves face into a darker part of the room. In a few days, the leaves will be facing the window again. The leaves have moved by themselves. Sunflowers turn their heads to follow the sun as it moves across the sky each day.



Figure 1 a Major Mitchell's Cockatoo in flight; **b** sunflowers turn to follow the Sun as it moves across the sky.



Figure 2 Living things reproduce.



Figure 3 Living things need nutrients to survive.

R Living things can REPRODUCE

Reproduction is the process by which living things create new life. Animals mate and produce offspring, plants produce seeds that grow into new plants, and bacteria divide to produce more bacteria. Without reproduction, living things would become extinct.

N Living things need NUTRITION

All living things need **nutrients** to survive. Animals obtain most of their nutrients by eating food and drinking. Plants absorb nutrients through their roots, while fungi have structures called hyphae that absorb nutrients from decaying organisms. Plants are classified as **autotrophs**, which means they make their own food. Animals and fungi are **heterotrophs**, which means they rely on other organisms for food.

G Living things GROW as they get older

All living things grow during their lives. Mushrooms start off as tiny spores. Humans are born as babies, developing into children, teenagers and then adults. Tadpoles will hatch from their eggs and then metamorphose into adult frogs. In every case, an organism, when fully grown, resembles its parents.



Figure 4 Living things grow during their lives. Tadpoles hatch from eggs and grow into frogs.

nutrient
a soluble substance that an organism needs to live and grow; usually taken in from the environment

autotroph
an organism that makes its own food (such as plants)

heterotroph
an organism (such as fungi) that needs to absorb nutrients from other living things

stimulus
any information that the body receives that causes the body to respond

R Living things RESPOND to change

All living things respond to their environment. For example, a Venus flytrap snaps shut in response to the **stimuli** of an insect landing in its trap. The sunflowers shown in Figure 1 are responding to the changing stimuli of light and warmth. When an animal realises it is being chased, it might run or swim away. It is responding to stimuli (the sight and sound of a charging predator) in its environment.

E Living things EXCHANGE GASES with their environment

Plants and animals have organs and structures that allow them to exchange oxygen and other gases. For example, all mammals use their lungs to inhale oxygen and then exhale carbon dioxide. Fish have gills, while amphibians exchange gases mainly across their skin.

W Living things produce WASTES

We, like other animals, take in food, water and air to fuel our bodies. Chemical reactions occur in our bodies and wastes are produced as a result. We get rid of these wastes by exhaling, sweating, urinating and defecating (emptying our bowels). Plants get rid of their wastes through their leaves.

W Living things require WATER

All living things need water to sustain life. For example, water transports substances in our bodies to where they are needed, and it is involved in many essential chemical reactions. In humans, water plays a number of roles, including the maintenance of body temperature.

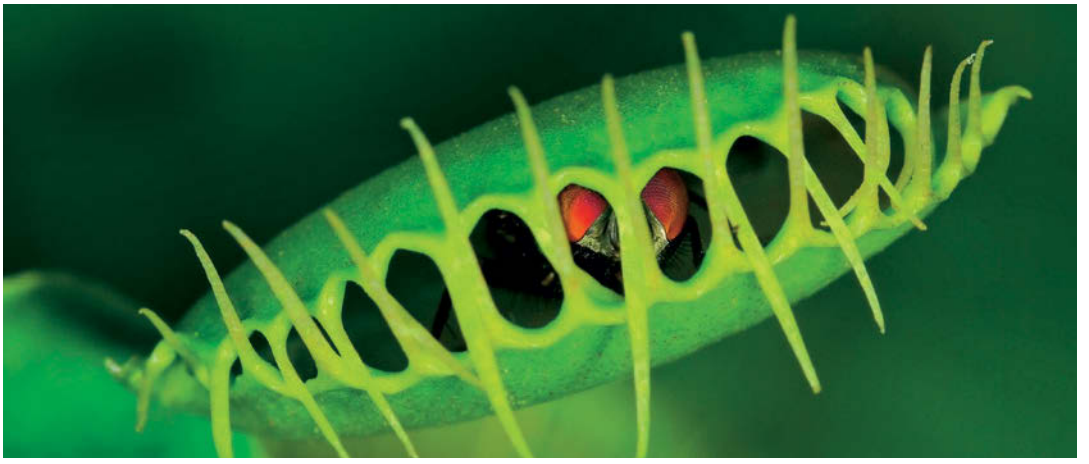


Figure 5 A Venus flytrap has modified leaves with 'teeth' that snap shut when it detects stimulus on its surface. The prey is unable to escape and will be digested by the plant.



Figure 6 Fish exchange gases with the environment through their gills.

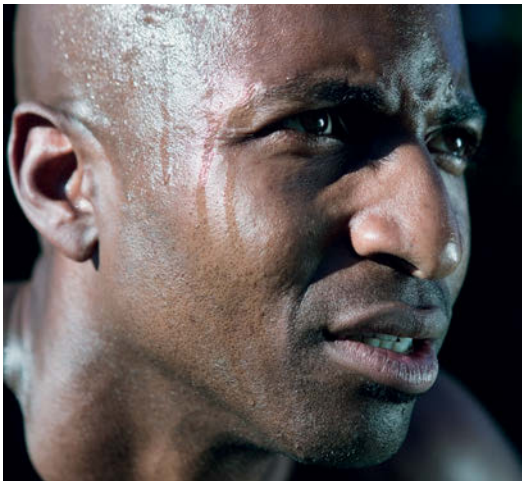


Figure 7 Sweating is one way humans maintain body temperature.



Figure 8 The human body uses water for many jobs.

Classifying living things based on structures

Living organisms have similarities and differences in their physical structures that allow them to perform each of the characteristics described above. These can be used to classify them into more specific groups. For example, organisms that have feathers and wings, which they use to fly, are classified as birds. Many Australian mammals are classified as marsupials because they have a pouch in which the young develop.

Plants can be classified based on their reproductive structures. Those that have flowers to attract pollinators are angiosperms, and those that do not are gymnosperms.

Non-living or dead?

Something classified as living needs nutrition and water, and is able to move by itself, reproduce, exchange gases, grow, respond to stimuli and produce wastes. If something doesn't have these characteristics, it would seem logical to assume that the thing is **non-living**.

But what about something that is dead? Something dead, such as a dried flower or an Egyptian mummy, was once living. When it was alive, it did have the characteristics of a living thing. Something that is non-living, such as a computer or your watch, never had these characteristics.

Interactive
Classifying living, non-living and dead

non-living
something that has never had the characteristics of a living thing

Check your learning 10.2

Recall and explain

1 **Describe** the eight characteristics that all living things have in common. Give an example of each.

Apply and analyse

2 **Distinguish** something that is non-living from something that is dead.

3 **Consider** the things listed below. With a partner or by yourself, decide whether each of the items should be classified as living, dead or non-living.

- Eucalypt tree
- Water
- Paper
- Robot
- Leather belt
- Wombat
- Roast chicken
- Chair

Evaluate and create

4 Use the characteristics of a living thing to decide if a bushfire is alive. **Explain** your answer.

Skills builder: Questioning and predicting

5 **Analyse** the image of the Venus flytrap in Figure 5.

a What physical structures can you observe that would help the plant to live?

b Write a scientific question about one of your observations. (THINK: What would you like to know more about? Your question should be specific and easily tested.)

10.3 Classification keys are visual tools

In this topic you will learn that:

- simple keys can be used to identify a range of plants and animals.

key
a visual tool used in the classification of organisms

branched key
a method of identifying a species using questions that lead to further questions and eventually to the identification of the species

dichotomous key
a diagram used in classification; each 'arm' of the key contains two choices

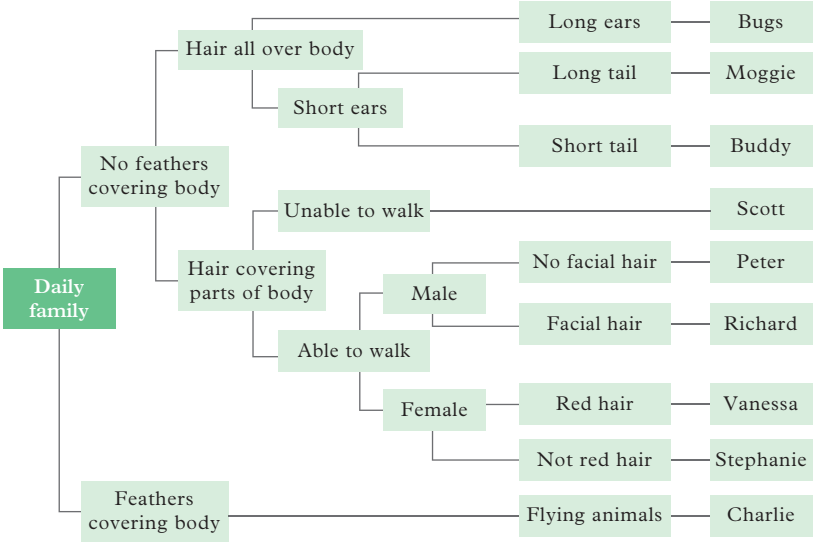
A **key** is a visual tool used in the classification of organisms. A key is often more useful than a list of characteristics and similarities of each group. A **branched key** (it looks like a tree) helps us see how a particular member of the group fits in with other organisms in the group.

When you visit an outdoor market, you may wander around for some time before you find what you want. A supermarket is more organised, with similar items grouped together. Scientists use a system similar to this to sort (or classify) things into groups. The system makes the names and descriptions of organisms easier to find.

Using dichotomous keys

One common type of key is called the **dichotomous key** (pronounced 'dye-COT-o-muss') because the branches always split into two (*di* means 'two'). Scientists use this type of key to make simple 'yes' or 'no' decisions at each branch. For example, does the animal have fur (yes/no)? Does it have scales (yes/no)? Each answer leads to another branch and another question. This key only works if the animal has already been identified by someone else. A newly discovered organism would need to be studied first, and then new branches added to an existing key.

Interactive
Using a dichotomous key



1	No feathers covering body	Go to 2
	Feathers covering body	Go to 9
2	Hair all over body	Go to 3
	Hair covering parts of body	Go to 4
3	Short ears	Go to 5
	Long ears	Bugs
4	Unable to walk	Scott
	Able to walk	Go to 6
5	Long tail	Moggie
	Short tail	Buddy
6	Male	Go to 8
	Female	Go to 7
7	Red hair	Vanessa
	Not red hair	Stephanie
8	No facial hair	Peter
	Facial hair	Richard
9	Flying animals	Charlie

Figure 1 Dichotomous keys for Dr Daily's family: on the left is a branched key, and on the right a tabular key. Both provide the same outcome.

CHALLENGE
10.3: Dichotomous key
Go to page **373**.

Dr Daily's family

Dr Daily loved to send out Christmas cards with a family photo on the front. One year, just for fun, he included two dichotomous keys to help everyone identify all his family and pets.

Use the picture of Dr Daily's family (Figure 2) and one of the dichotomous keys provided (Figure 1) to work out who is who.



Figure 2 Dr Daily's family

Tabular keys

If a scientist is going out into the bush to study plants and animals, a large drawing like the branched key on the left in Figure 2 may not be useful. Instead, a field guide or tabular key, such as that shown on the right of Figure 2, can be used. This is used in the same way as the branched key version. Two choices are offered at each stage. When a decision is made, the scientist is led to the next characteristic choice.

Check your learning 10.3

Recall and explain

1 **Describe** a dichotomous key.

2 **Explain** why it is called 'dichotomous'.

Apply and analyse

3 Which of the following descriptions would be good to use to **classify** a group of birds in a dichotomous key? Give a reason why each one is or is not a good method of classification.

- **a** Is eating bird seed
- **b** Has a blue stripe above the eye
- **c** Has a wingspan of 32 centimetres
- **d** Has a broken leg
- **e** Is sitting on the ground
- **f** Has a high-pitched, bell-like song
- **g** Has brown tail feathers

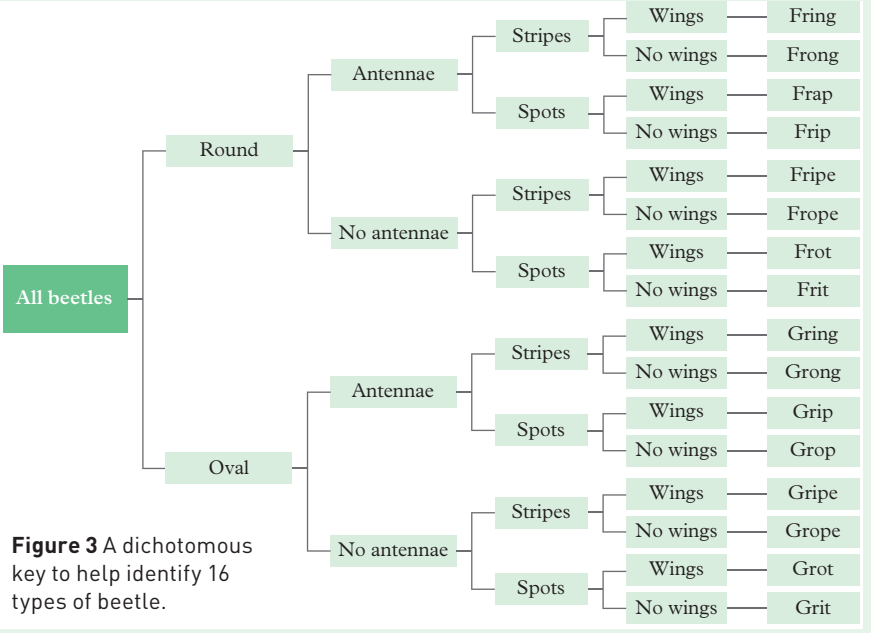


Figure 3 A dichotomous key to help identify 16 types of beetle.

4 **Interpret** the dichotomous key in Figure 3.

- **a** **Identify** and name the four beetles in Figure 4

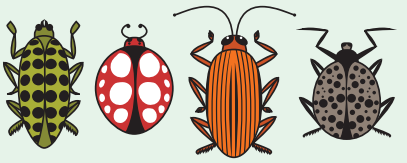


Figure 4 Types of beetles

- **b** **Construct** a simple sketch of the following.
  - **i** Frope beetle
  - **ii** Gring beetle
  - **iii** Gripe beetle
  - **iv** Frong beetle

Evaluate and create

5 **Construct** a key that could be used to identify laboratory equipment. Include these items: tripod stand, Bunsen burner, gauze mat, 50 mL beaker, 150 mL beaker, 100 mL measuring cylinder, 10 mL measuring cylinder, 500 mL beaker, 500 mL measuring cylinder, retort stand, clamp.

Skills builder: Processing and analysing information

6 Refer to Figure 1. How might you adjust the dichotomous key if Dr Daily's 'family' included his sister, Melinda; his mother, Frances; his two daughters, Stef and Gemma (Stef wears glasses); and his pet lizard named Stealth but not a bird named Charlie?

10.4 Classification systems change

In this topic you will learn that:

- in the Linnaean classification system, each organism is given a unique, two-word name
- classification systems continue to change as new technologies develop and improve our understanding of living things.

taxonomist
a scientist who classifies living things into groups

kingdom
a taxonomic rank that is composed of smaller groups called phyla (historically kingdoms were the highest taxonomic rank; now superseded by domains)

Linnaean taxonomy
a system of classification first developed by Carolus Linnaeus (1707–78), in which all organisms are grouped into one of five kingdoms

phylum
a level of taxonomic classification below kingdom and above class

class
a level of taxonomic classification below phylum and above order

order
a level of taxonomic classification below class and above family

The earliest **taxonomists** divided all living things into two groups: plants and animals. As new technologies developed, our understanding of the natural world improved and further **kingdoms** were identified.

The Linnaean taxonomy

When trying to find your house on Google Earth, you first find Australia and then the state you live in. Each time, you narrow your search closer to your town, your suburb, your street until you finally find your house. In a similar way, Linnaeus came up with a system that is still used today to identify living things: the **Linnaean taxonomy**.

Linnaeus tried early classification systems but found their descriptions to be too long. He decided a simpler system was needed. He changed the descriptions to single words and reduced the number of classification groups to seven.

The Linnaean system for classifying all living things starts with large groups called kingdoms, and then divides into smaller groups called **phyla** (singular 'phylum'). Each phylum has several **classes**. The classes have **orders**, and so on. There are seven levels – kingdom, phylum, class, order, family, genus and species, with each level having fewer types of organisms that belong in them.

(Tip: Some people use the following mnemonic to remember the Linnaean system: '**K**ing **P**hillip **C**rawled **O**ver **F**our **G**ooey **S**nails'.)

KINGDOM: Animalia
e.g. insect, fish, bird, lizard, kangaroo, fox, lion, jungle cat, domestic cat

PHYLUM: Chordata
e.g. fish, bird, lizard, kangaroo, fox, lion, jungle cat

CLASS: Mammalia
e.g. kangaroo, fox, lion, jungle cat, domestic cat

ORDER: Carnivora
e.g. fox, lion, jungle cat, domestic cat

FAMILY: Felidae
e.g. lion, jungle cat, domestic cat

GENUS: *Felis*
e.g. jungle cat, domestic cat

SPECIES: *catus*
domestic cat



Figure 1 The Linnaean classification system uses seven different levels. It is used to give names to living things such as the domestic cat.

CHALLENGE
10.4: Can you understand scientific names?
Go to page **374**.

Giving organisms a precise name

All organisms are named using the last two groupings on Linnaean system of classification: the genus and the species.

In the double-name (or **binomial**) system, the **genus** group name always starts with a capital letter. The second word is the species name, and it does not have a capital letter. The double name is always written using italics.

A **species** is a group of organisms that look similar to each other. When they breed in natural conditions, their offspring are fertile – in other words, they can also breed. All domestic cats belong to the one species because they can breed together and have kittens.

Microscopes changed classification

The invention of microscopes allowed scientists to view organisms in much greater detail. Taxonomists came to realise they could also classify organisms into groups based on their cells.

Many living things, such as bacteria, consist of only one cell. These are single-celled or **unicellular** organisms. Any living thing with more than one cell is **multicellular**.

Taxonomists ask three questions when they are trying to classify the cells of an organism:

1. Does the cell keep all its genetic material (called DNA) inside a **nucleus**? The nucleus protects the DNA that carries all the instructions for staying alive.
2. Does the cell have a **cell wall** around it for extra support?
3. Does the cell use sunlight to make its own nutrients (autotroph)? Plant cells can do this, but fungi (like mushrooms) need to absorb their nutrients from other living things (heterotroph).

It is the correct combination of these three features that help divide all living things into the first big group called kingdoms.

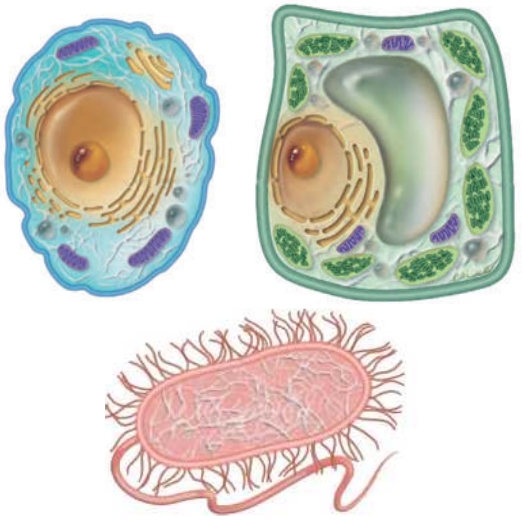


Figure 2 Simple animal (top left), plant (top right) and bacterial (bottom) cells

nucleus
the control centre of a cell that contains all the genetic material (DNA) for that cell

cell wall
a structure that provides support around some cells

binomial name
a double-name system created by Linnaeus to name organisms; the first name is the genus and the second name is the species

genus
a group of closely related species

species
a group of individuals that can breed and produce viable, fertile offspring

unicellular
living things consisting of one cell (such as bacteria)

multicellular
any living thing with more than one cell

Check your learning 10.4

Recall and explain

1. **Identity** the seven levels of Linnaean classification used to identify an organism. Write them in order from largest to smallest level of organisation.
2. **Describe** the binomial system of classification.
3. **Explain** how the introduction of the microscope changed the way taxonomists classified organisms.

Analyse and apply

4. Select three species, each from a different kingdom. For each organism:
   a. **describe** its appearance
   b. **identify** its common and scientific names.

Evaluate and create

5. In groups or individually, create a mnemonic that helps you to remember the seven levels of Linnaean classification.

Skills builder: Planning investigations

6. Georgia is asked to classify a species of butterfly. **Suggest** how Georgia might find the information she needs to discover its binomial name. (THINK: Does this require first-hand and secondary sources?)



Figure 3 Have you eaten a *Musa sapientum* recently? This is the Linnaean name for a banana.

10.5 Living things are classified into five Kingdoms

In this topic you will learn that:

- organisms can be classified into five kingdoms – Animalia, Plantae, Fungi, Protista and Monera – based on key structural features
- micro-organisms can only be seen under a microscope and include bacteria and most protists.

Interactive
Kingdoms

Kingdom Animalia

All organisms in Kingdom Animalia are multicellular. Each cell in these organisms stores the genetic material (DNA) in a small internal structure called the nucleus. Animal cells do not have a cell wall. Animals gain energy from consuming other living things. Humans belong in this kingdom. Scientists who study animals are called **zoologists**.

zoologist
a scientist who studies the behaviour, physiology, classification and distribution of animals



Figure 1 Kingdom Animalia: **a** Proboscis monkey (*Nasalis larvatus*), with the world's largest nose; **b** Port Jackson shark; and **c** damselfly

Kingdom Plantae

Kingdom Plantae includes trees, vines, bushes, ferns, mosses, weeds and grasses. They all carry out **photosynthesis**, using sunlight to gain energy and make their own food (autotrophs). They are multicellular and their cells have a cell wall around the outside of the cell, as well as a nucleus inside the cell containing DNA. Scientists who study this kingdom are called **botanists**.







Figure 2 Kingdom Plantae: **a** *Rafflesia*, the world's smelliest plant, is found in South-East Asia. Its flower can measure up to 90 centimetres across and weigh about 11 kilograms. It gives off a rotten meat odour when it blossoms to attract insects; **b** flowering gum; **c** moss

Kingdom Fungi

Kingdom Fungi includes mushrooms, toadstools, yeasts, puffballs, moulds and truffles. Some fungi grow in wood and soil and develop from tiny spores. Fungal cells also contain DNA in a nucleus. Like animals, fungi are heterotrophic: they do not make their own food. Instead, they feed on the remains of dead animals and plants. What distinguishes fungi from animals is that fungal cells possess a cell wall. Some fungi can cause diseases, such as tinea (athlete's foot). **Mycologists** study fungi.

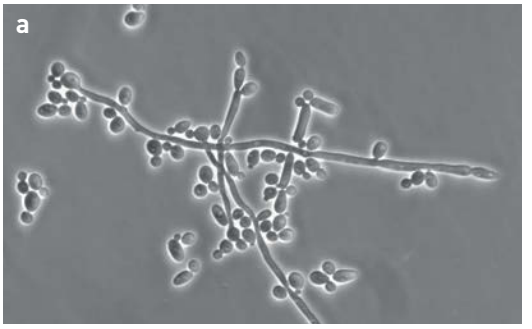




Figure 3 Kingdom Fungi: **a** The hair-like filaments of the yeast *Candida albicans* as seen under a microscope; **b** mould; **c** mushrooms

Monera and Protista: Microscopic organisms

When the microscope was invented, scientists began to understand and document the differences between organisms at a cellular level. It also helped them to realise the existence of organisms that we could not see without a microscope.

Micro-organisms, or microbes, are organisms that are so small that they can only be seen with a microscope. They include all bacteria from Kingdom Monera and most species from Kingdom Protista. **Microbiologists** are the scientists who study micro-organisms which belong to Kingdoms Monera and Protista.

photosynthesis
the chemical process plants use to make glucose and oxygen from carbon dioxide and water

botanist
a scientist who studies plants

mycologist
a scientist who studies the Kingdom Fungi





Figure 4 A light microscope can be used to see some larger micro-organisms.

micro-organism
a microscopic organism; a microbe

microbiologist
a scientist who studies micro-organisms

Kingdom Monera

The development of microscopes led to the discovery of Kingdom Monera. This kingdom is made up of the simplest and smallest living things. There are approximately 75 000 different organisms in Kingdom Monera, and they are all unicellular and have a cell wall but contain no nucleus.

bacteria
unicellular organisms with a cell wall but no nucleus

Bacteria are the most common organisms in Kingdom Monera. Many people think of bacteria as harmful to humans, but this is not always true. For example, good bacteria in our intestines help us to digest the food we eat. Bacteria in the soil break down rubbish and wastes produced by animals (especially us). Without bacteria, we would be surrounded by mountains of smelly rubbish. Bacteria have also been put to use by humans to make food, such as cheese and yoghurt.

There are many different types of bacteria that come in all different shapes. As you can see in Figure 5, bacteria can look:

- spherical (cocci)
- rod shaped (bacilli)
- curved or spiral shaped (spirillum).

The bacteria can also be classified based on the way they are grouped:

- individually
- in pairs (diplo)
- in chains (strepto)
- in clusters (staphylo).



Figure 5 Kingdom Monera, as seen under a microscope: **a** *Spirillum volutans*; **b** *Lactobacillus casei*; **c** *Streptococcus pyogenes*

Kingdom Protista

In Kingdom Protista, approximately 55 000 species are currently identified. The cell structure of these protists is more complex than that of the Monera, with all having DNA contained within a nucleus.

Most, but not all, organisms in Kingdom Protista are unicellular and microscopic. Often, organisms that don't fit into any other kingdom will belong in Protista. Many taxonomists believe the kingdom should be classified further based on the significant diversity that exists at both the cellular and whole organism levels. For example, protists can range in size from unicellular to much larger multicellular organisms. The microscopic **amoeba**, an organism that changes its shape to trap food (heterotrophic), and the large giant kelp (seaweed), which is autotrophic, belong to this group. Plankton, the tiny sea creatures eaten in their millions by whales, are part of this kingdom.

amoeba
a type of single-celled organism belonging to the Protista kingdom

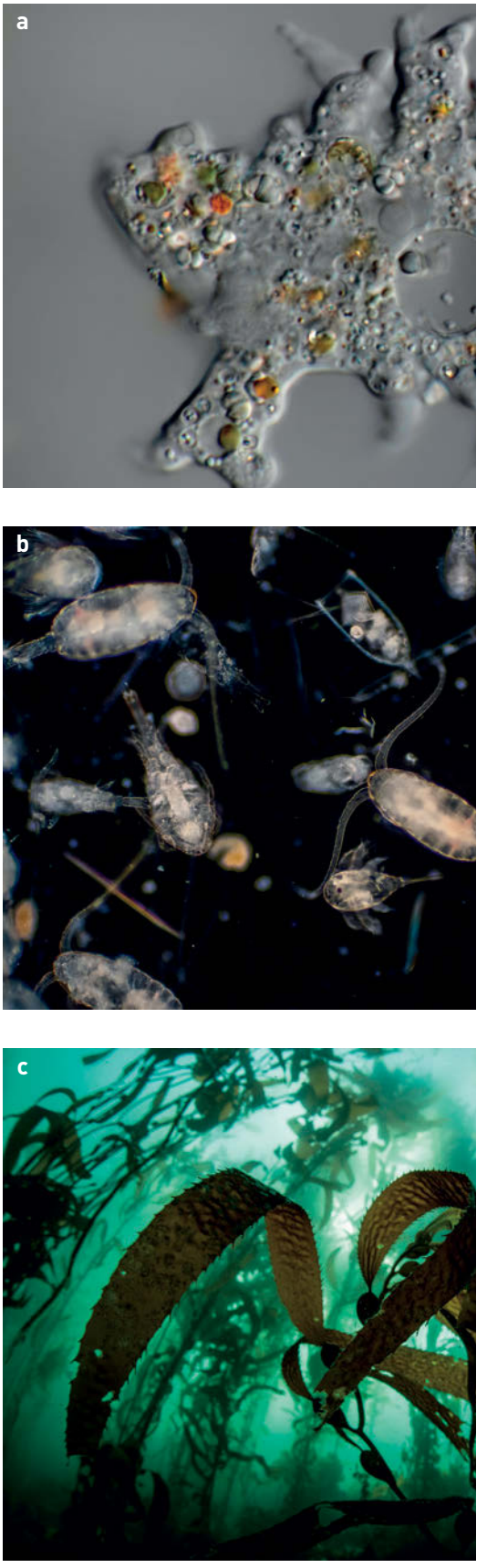


Figure 6 Kingdom Protista: **a** amoeba; **b** plankton; **c** the large giant kelp

The future of classification

Research continues in the area of classification. Given the diversity that exists, particularly in the Monera and Protista kingdoms, it is likely that the classification of these kingdoms will continue to change as technologies improve and more information and evidence become available.

For example, the Archaeans, first discovered in the 1970s, are a group of organisms previously thought to be bacteria and therefore belonging to Kingdom Monera. They have since been found to have very different cellular structures and to live only in extreme conditions, such as very salty or hot waters.

This has led to a 'three-domain system' being proposed. These domains would create an eighth level of classification that sits above kingdom. This system proposes one domain – Eukaryota – for plants, animals, protists and fungi. The single-celled organisms currently in Kingdom Monera would then be split into two domains – Eubacteria and Archaea – according to differences in their cellular structures and genetic material.

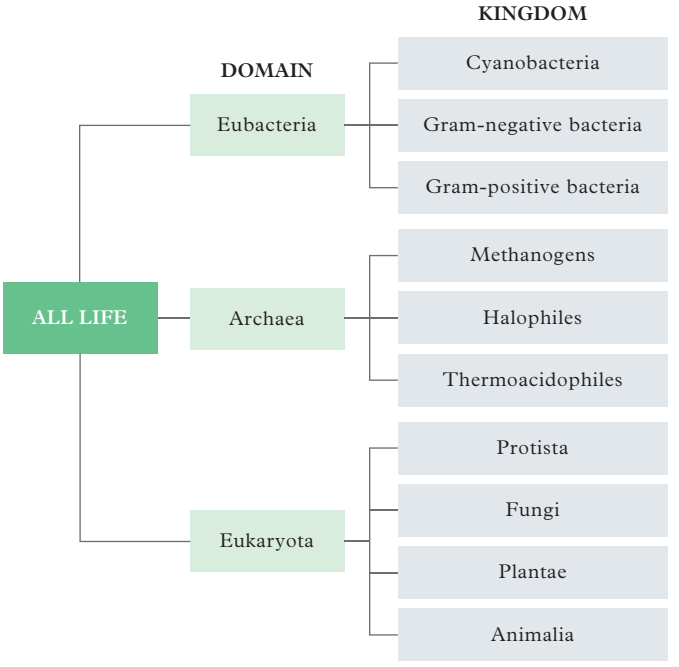


Figure 7 The three-domain system of classification

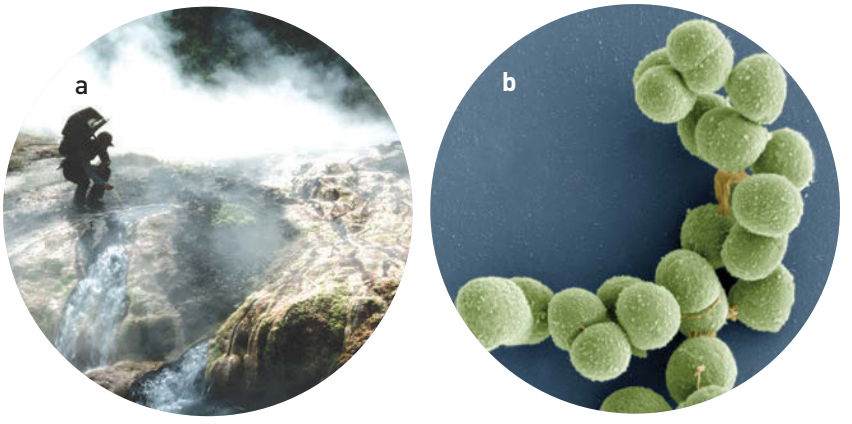


Figure 8 a Biologists collecting Archaea samples in the hot springs of the Obsidian Pool in Yellowstone National Park, USA; **b** a magnified view of a clump of Archaean organisms

Check your learning 10.5

Recall and explain

1 **Identify** two features that all animals have in common.

2 **Explain** why bacteria are referred to as micro-organisms.

3 **Identify** two organisms that belong to Kingdom Protista.

Analyse and apply

4 **Compare** the structural difference between cells in the Plantae and Fungi kingdoms.

5 **Examine** Figure 9. Based on your understanding of how bacteria are classified, what is the most likely name for this organism.

Evaluate and create

6 **Predict** how an understanding of genetic material might change classification in the future.

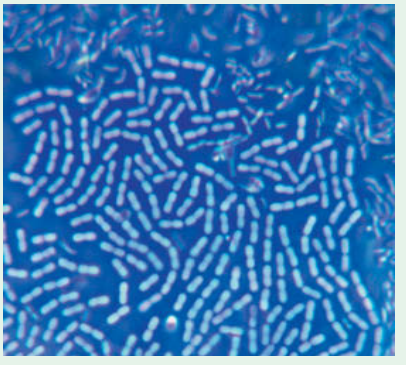


Figure 9 Examine the shape of this bacteria.

Skills builder: Communicating

7 **Construct** a table that compares and contrasts the structural features of each kingdom. (THINK: How can you group features together?)

10.6 Animals that have no skeleton are called invertebrates

In this topic you will learn that:

- Kingdom Animalia can be divided into invertebrates and vertebrates
- invertebrates do not have a spine (backbone).



Figure 1 The giant squid is an invertebrate.

Video
Squid dissection

endoskeleton
an internal skeleton

vertebrate
an organism with an endoskeleton (internal skeleton)

exoskeleton
an external skeleton

invertebrate
an organism with an exoskeleton (external skeleton) or no skeleton at all

Kingdom Animalia contains approximately 35 phyla. Most commonly, scientists divide them into two main groups: vertebrates and invertebrates.

Grouping animals: internal or external skeleton?

In the same way as when creating any kind of dichotomous key, dividing the animal kingdom into groups first requires a question. The system scientists use to divide animals into groups is based on their structure. The question is: 'Does this animal have an internal or external skeleton?'

Animals with an internal skeleton (**endoskeleton**), such as cats, humans and birds, are put in a group called **vertebrates**. Because these animals have a central spinal cord that threads its way between the vertebrate bones, the phylum is called Chordata. Other animals with an external skeleton (**exoskeleton**), such as insects and crabs, and those with no skeleton at all, such as slugs, are known as **invertebrates**. Invertebrates dominate the animal kingdom.

There are more invertebrates on the Earth than vertebrates: 96% of all animals are invertebrates. The giant squid (see Figure 1), huge as it is, has no backbone. As well as enormous animals like this, thousands of tiny insects and other creatures belong to the invertebrate group.

Identifying invertebrates

In the same way that vertebrates are classified, invertebrates are also grouped into six main groups of phyla on the basis of their characteristics. Characteristics used to classify invertebrates include the presence of a shell or hard cover, tentacles or spiny skin. Organisms with similar features are placed in the same group. The dichotomous tabular key in Table 1 can be used to place an organism into a particular phylum.

Table 1 Tabular key for identifying invertebrates

1	Body spongy, with many holes	Poriferan
	Body not spongy	Go to 2
2	Soft body, no shell	Go to 3
	Outside shell or hard cover	Go to 6
3	Many tentacles or arms	Go to 4
	Long body without tentacles	Go to 5
4	Tentacles around the mouth of a sac-like body	Cnidarian
	Arms with suction discs	Mollusc
5	Soft body, large foot	Mollusc
	Worm-like or leaf-like	Nematode, platyhelminth or annelid
6	Proper shell or smooth, hard covering	Go to 7
	Spiny skin with rough covering	Echinoderm
7	Limbs in pairs	Arthropod
	Shell, no segments, large foot	Mollusc

SKILLS LAB **10.6:** Dissecting skeletons
Go to page **375**.

CHALLENGE **10.6:** Identifying invertebrates
Go to page **376**.

Arthropods

Arthropods have segmented bodies, paired and jointed legs and an exoskeleton. Examples include insects, spiders, centipedes and scorpions.

Poriferans

Poriferans have spongy bodies with holes and are found in water, attached to rocks. Examples include breadcrumb sponges and glass sponges.

Molluscs

Molluscs have soft bodies and usually have a protective shell. Examples include snails, octopi, oysters and slugs.

Cnidarians

Cnidarians live in water and have soft, hollow bodies and tentacles. Examples include coral, jellyfish and anemones.

Nematodes, platyhelminths and annelids

Nematodes, platyhelminths and annelids have soft, long bodies, and they can be segmented, flat or round. Examples include leeches, tapeworms and flatworms.

Echinoderms

Echinoderms have rough, spiny skin, arms that radiate from the centre of their bodies, and are found in the sea. Examples include sea urchins, sea cucumbers and brittle star.



Figure 2 Some commonly found invertebrate phyla

Check your learning 10.6

Recall and explain

1 Animals are divided into two main groups.
   a **Identify** the names of the groups.
   b What do the names of these two groups mean?

2 **Identify** two examples of animals with an exoskeleton.

3 **Identify** two examples of animals with no skeleton at all.

Apply and analyse

4 Beetles have segmented bodies and jointed legs. **Classify** them into a phylum.

Evaluate and create

5 On the Earth, 80% of animals are arthropods.
   a Which characteristic does their name refer to? (Hint: Think of 'arthritis' and 'podiatrist'.)
   b **Construct** three diagrams of different arthropods and label the features that make them part of this phylum.

Skills builder: Processing and analysing information

6 Use the tabular key (Table 1) to classify the organism in Figure 3. (THINK: What features can you observe to answer the questions in the key?)



Figure 3 Ladybugs are also known as coccinellidae.

10.7 Vertebrates can be organised into five classes

In this topic you will learn that:

- vertebrates have a spine (backbone)
- the five classes of vertebrates are distinguished by their physical features.

Interactive
Classes of vertebrate

endotherm
an organism with a constant body temperature

ectotherm
an organism with a body temperature that changes with the environment

placental mammal
a type of mammal that carries the fetus in a placenta

marsupial
a mammal that gives birth to young that continue to develop in their mother's pouch

monotreme
a mammal that lays eggs

Vertebrates are animals with a spine (or backbone). The vertebrate group can be broken down into further subgroups called classes based on:

- their body covering
- how their young are born
- their body temperature.

Vertebrates either have a constant body temperature (**endotherm**) or a body temperature that changes with the environment (**ectotherm**).

Class Mammalia

Mammalia is a class of vertebrates well known to many people. Many of our pets belong to this class: horses, dogs, cats, rabbits, guinea pigs and mice. We belong to this class too.

Mammals are animals with hair or fur, and they have a constant body temperature. Female mammals, with the exception of monotremes, give birth to live young and feed their young with their own milk.

Class Mammalia can be further broken down into three subgroups, as shown in Figure 1. The main feature used to separate mammals is the way in which their young develop. **Placental** mammals give birth to relatively well-developed young (such as dingoes), **marsupial** young develop mostly in the pouch rather than in the womb (such as kangaroos) and **monotremes** lay eggs (such as platypi). However, no matter the type of mammal, they all feed their young milk.

Class Aves

All birds belong in class Aves. Like mammals, they are endotherms. Two of their main distinguishing characteristics – the way they differ from the other classes – are their covering of feathers and scaly legs. All animals in this class lay eggs with a hard shell.



Figure 1 The three subgroups of mammals: placentals, marsupials and monotremes



Figure 2 Class Aves contains all birds, including this Gouldian finch.

CHALLENGE
10.7: Who are the vertebrates?
Go to page **377**.

Class Reptilia

The skin of reptiles, such as snakes and lizards, is usually covered in a layer of fine scales. Reptiles use lungs to breathe, even if they live under water (sea snakes). These animals are also ectotherms – we do not use the term 'cold-blooded' to describe them because a lizard that has been lying in the sun has very warm blood, even though at night its blood is cool.

Turtles also belong to this class. Many people become confused by the hard outer shell of turtles and tortoises, thinking it is an exoskeleton. Underneath the shell, however, there is a hard backbone with a nerve cord running through it.

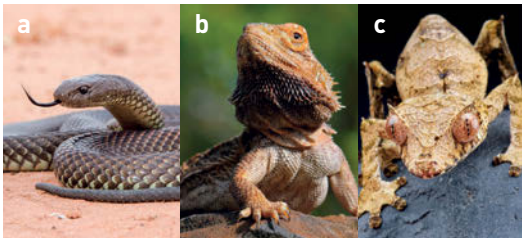


Figure 3 Class Reptilia: **a** king brown snake; **b** bearded dragon; and **c** gecko



Figure 4 Despite having a hard outer shell, turtles and tortoises have a hard backbone with a nerve cord running through it.

Class Amphibia

Like reptiles, amphibians are ectotherms; however, their skin is usually soft and slimy to touch. They lay their eggs, without shells, in water. For the first part of their life, they have gills and live in the water. As they get older, lungs develop and they become able to live on land. The only remaining group of amphibians in Australia is frogs. In other parts of the world, toads, caecilians and salamanders may be found.

Class Pisces

Most fish are ectotherms. They are covered in a layer of scales and most have fins. They spend all their life in water and so need gills to breathe. Fish are further grouped according to their skeleton. Sharks, rays and skates have a skeleton made entirely of cartilage, whereas all other fish have bony skeletons.

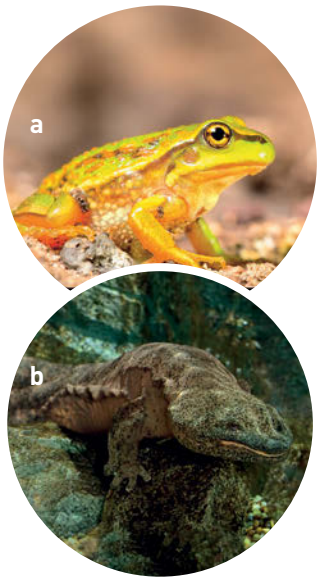


Figure 5 Class Amphibia: **a** growling grass frog; **b** Chinese giant salamander

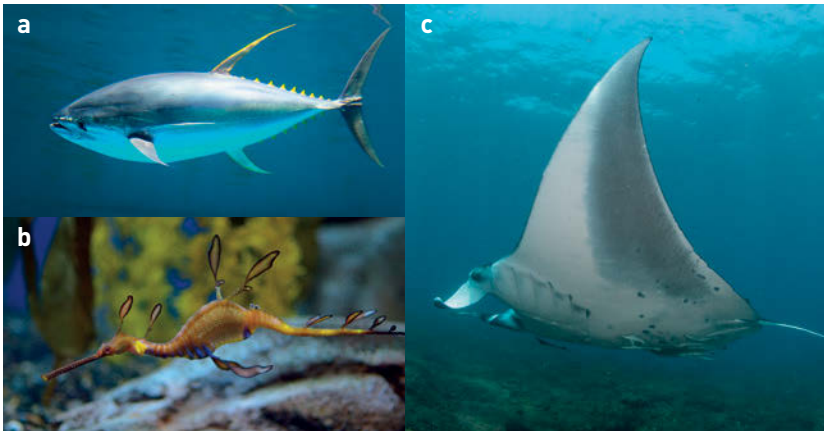


Figure 6 Class Pisces: **a** tuna; **b** weedy seadragon; **c** manta ray

Check your learning 10.7

Recall and explain

1 **Recall** the main characteristics of mammals.

Apply and analyse

2 A dolphin lives in the ocean and has fins. **Classify** this dolphin into a class.

3 A flying fox can glide through the air like a bird but is covered in fur. **Classify** the flying fox into a class.

4 What does a placental mammal look like when it is born? **Contrast** this with monotremes and marsupials.

Evaluate and create

5 Seals have fins like fish and live on the land and in the water like amphibians.

a **Investigate** how a seal's young are born.

b Given that the seal has long whiskers, **classify** the vertebrate into a class.

6 The vertebrates have five classes: Mammalia, Reptilia, Amphibia, Aves and Pisces. What are the more common names for these classes?

Skills builder: Communication

7 **Construct** a dichotomous key to show the five classes of vertebrates. (THINK: What information needs to be included to explain the different classes to someone who does not know about them?)

10.8 Plants can be classified according to their characteristics

In this topic you will learn that:

- plants can be classified according to their characteristics.

phloem
the vascular tissue found in plant stems that carry the sugars around the plant

vascular tissue
(in plants) tube-like structures that transport water and nutrients from the roots to the leaves

non-vascular
(in plants) lack transport vessels

xylem
the tissue in plants that carries water from the roots to the rest of the plant

As you saw earlier in this chapter, plants belong in one of the five kingdoms of living things. All plants are multicellular organisms that are able to convert the Sun's energy into food. This does not mean all plants look the same, however. Plants have a variety of different characteristics that allow us to classify them into different phyla.

Seeds or spores

Planting a seed and watching it grow is something most people have done at some stage. But not all plants have seeds. Some plants, such as ferns, produce spores. Spores are much smaller than seeds and only contain half the genetic material to make a fern. They can be found clinging to the underside of a fern frond.



Figure 1 Not all plants germinate from seeds. Ferns produce spores instead.

Vascular tissue

Plants, like all living things, need water to survive. Many plants use their roots to absorb water and transport it through tube-like structures called **xylem** to the leaves. Food (in the form of a sugar called glucose) produced in the leaves during photosynthesis is transported around the plant in **phloem**. This system of tubes is called the **vascular tissue** of the plant. But not all plants are so organised. **Non-vascular** plants, such as liverworts and mosses, need to live in damp places where they can absorb water and nutrients through the surface of their leaves. This is much more difficult and is why non-vascular plants tend to be very small and are restricted to damp environments.



Figure 2 Mosses and liverworts can absorb water through all parts of their structure.

The importance of flowers

Plants can be classified based on their reproductive structures. As mentioned earlier in the topic, many plants (angiosperms) use flowers to attract pollinators such as insects and birds. These pollinators transfer pollen between plants of the same species resulting in fertilisation and the production of seeds. Not all plants have flowers (gymnosperms). Conifers have needle-like leaves and produce cones instead of flowers. Pollen from one cone is often transferred to another cone (pollination) so that a seed can be produced.



Figure 3 Some plants use flowers or cones to produce seeds.

CHALLENGE
10.8: Identifying plants
Go to page **377**.

The classification of flowering plants

Flowering plants can be divided into two main groups. Monocotyledons (monocots) have a single leaf that grows from the seed. They can usually be recognised by the parallel veins in the leaves and by counting the number of petals in the flowers. Monocot flowers always have petals that are multiples of three.

Dicotyledons (dicots) grow two leaves from the seed. Their leaves have veins that are reticulated (spread out from a central vein), and they tend to have four or five petals on each flower.



Figure 4 The number of petals on a monocot flower is always a multiple of three.



Figure 5 A dicot flower

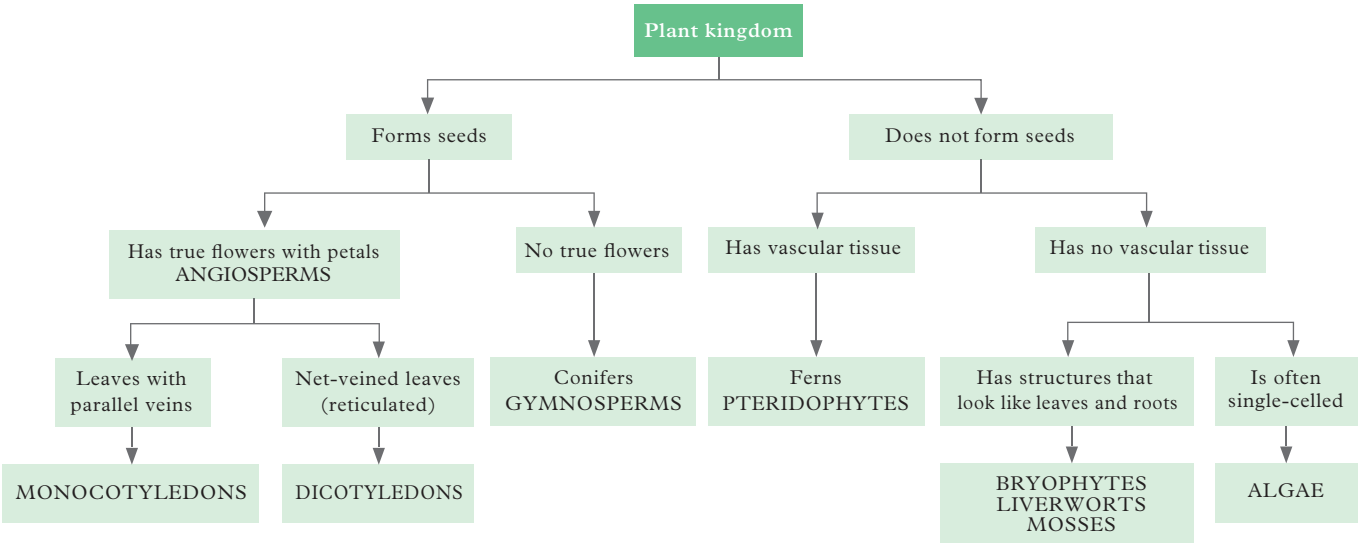


Figure 6 A sample plant key

Check your learning 10.8

Recall and explain

1 **Identify** two structural features that can be used to group plants.
2 **Explain** how conifers reproduce.
3 Use Figure 6 to answer the following questions:
   a **Identify** two characteristics of ferns.
   b **Identify** two characteristics of mosses.
   c **Identify** the differences between a monocotyledon and dicotyledon.

Apply and analyse

4 Are you likely to find mosses or liverworts growing in the desert? **Explain** your answer.
5 Who am I? I am large and green. I use sunlight to make my own food. I smell nice and like to come inside at Christmas. Some people do not like me because my leaves can be prickly and needle-like. I use a cone to help me reproduce. **Classify** me into a plant phylum.

Evaluate and create

6 Locate a plant in your school or home garden.
   a **Construct** a labelled diagram of the plant.
   b What features could you use to classify your plant?
   c **Identify** at least one feature that is not currently present that would help you classify your plant.

Skill builder: Problem solving

7 Is it better to be a vascular or non-vascular plant in a dry climate? **Evaluate** the advantages of vascular plants and non-vascular plants for surviving in dry weather. (THINK: What features help each type of plant to survive?)

10.9 Australian organisms have adapted

In this topic you will learn that:

- adaptations are the physical features or behaviours that help living things to survive and reproduce in their environment.

Plants and animals need to be suited to the area where they live if they are to have the best chance of survival. The survival of a species relies not only on the individuals of the population living healthy lives, but also on their ability to adjust to suit their environment. Australia has a wide variety of ecosystems, including deserts, tropical rainforests and open eucalyptus woodlands. In each case, there is a wide range of unique flora (plants) and fauna (animals) that have adaptations that enable them to survive.

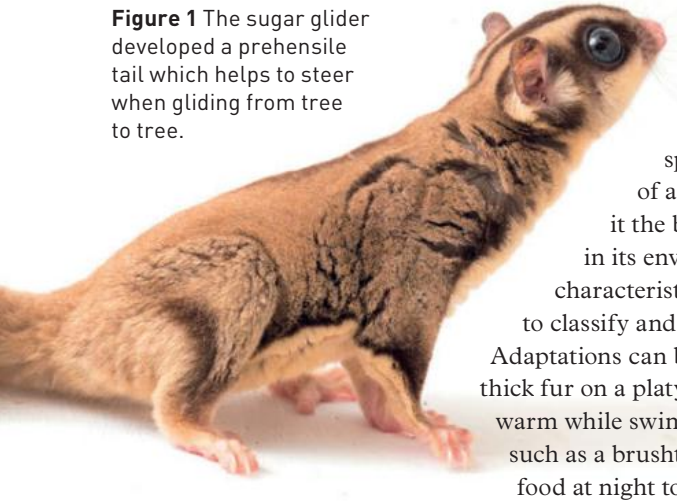


Figure 1 The sugar glider developed a prehensile tail which helps to steer when gliding from tree to tree.

What is an adaptation?

An **adaptation** is a specific characteristic of an organism that gives it the best chance of survival in its environment. These characteristics can often be used to classify and identify the organism. Adaptations can be physical, like the thick fur on a platypus' body to keep it warm while swimming, or behavioural, such as a brushtail possum foraging for food at night to avoid predators.

adaptation
a characteristic or feature of an organism that assists in its survival and reproductive success

How do adaptations arise?

Looking around your classroom, you will notice that even though you are all human and about the same age, you are all slightly different. The same applies to all species. There is variation in the characteristics found within a population. If environmental conditions change, individuals with characteristics better suited to the changes will be more likely to survive, reproduce and pass these favourable features on to their offspring. This is referred to as 'survival of the fittest'. Individuals without the favoured characteristic are less likely to survive and reproduce.

For example, a population of giraffes live in an area where food is scarce, but it is more available at the tops of tall trees. If the population has giraffes of different heights, the taller giraffes will be able to reach leaves that the shorter giraffes cannot. Over time, if the food availability stays the same, the population is likely to become taller because only the tall members of the species are able to survive and reproduce (see Figure 2).

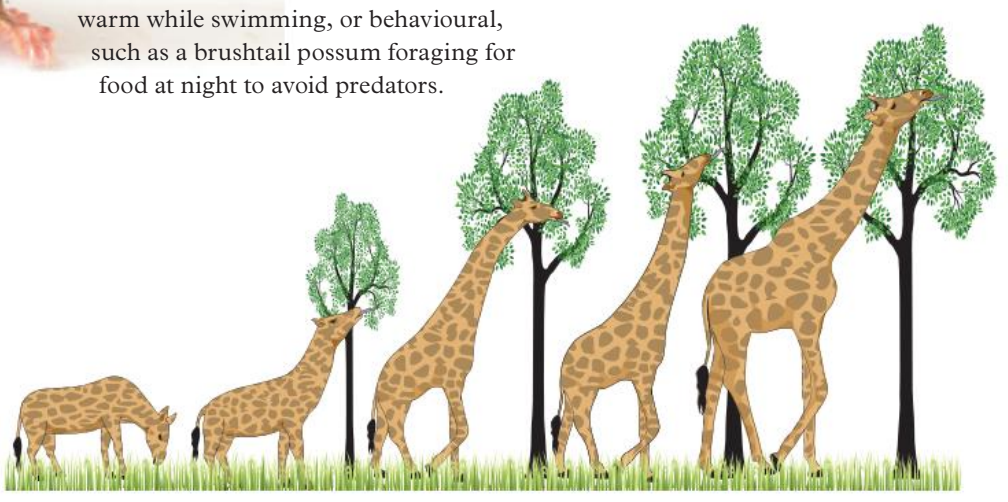


Figure 2 Adaptations occur over generations. Taller giraffes that are able to reach the food source high up in trees survive and produce tall offspring. The shortest giraffes that cannot reach the leaves do not survive and therefore do not reproduce.

CHALLENGE
10.9: Looking at eucalypt adaptations
Go to page **378**.

Australian animal adaptations

Australian fauna is unique in the world. It is dominated by marsupial mammals, with more than 250 found here. All other continents are inhabited mainly by placental mammals. Australia and Papua New Guinea are the only countries where monotremes are still found.

The common wombat

The common wombat has many adaptations to help it survive in Australia. The backward-facing pouch stops the mother from suffocating her young with soil as she digs her burrows underground. To dig their burrows, wombats are armed with powerful claws and rodent-like front teeth. They have a barrel-shaped body with short legs and a hard rump (lower back), which they can quickly reverse back up their burrow to prevent entry of, and even cause injury to, would-be predators. Wombats are usually nocturnal and produce distinctive cube-like faeces that they stack to mark their territory and attract mates.

The short-beaked echidna

The short-beaked echidna, a monotreme, is found throughout Australia. Echidnas have a long, strong snout that helps them to break logs and termite mounds in search of food. They have long, sticky tongues that are also useful for catching ants. Other physical adaptations include fur-like hair for warmth, spines for protection and sharp claws for digging.

The thorny devil

Reptiles are particularly well suited to Australia's dry, desert environment. The thorny devil uses the environment to regulate its temperature. When it wants to become active, it lies in the sun; however, when it is too hot outside, it hides in a burrow until the heat has passed.

One fascinating feature of the thorny devil is that it can drink water with its feet! It places its feet in a puddle, and water moves up its body by capillary action along grooves in the skin to the corner of its mouth.



Figure 3 The common wombat can be found in south-eastern Australia.



Figure 4 The short-beaked echidna's snout is adapted to eating ants.



Figure 5 The thorny devil has adapted to live in the Australian desert.

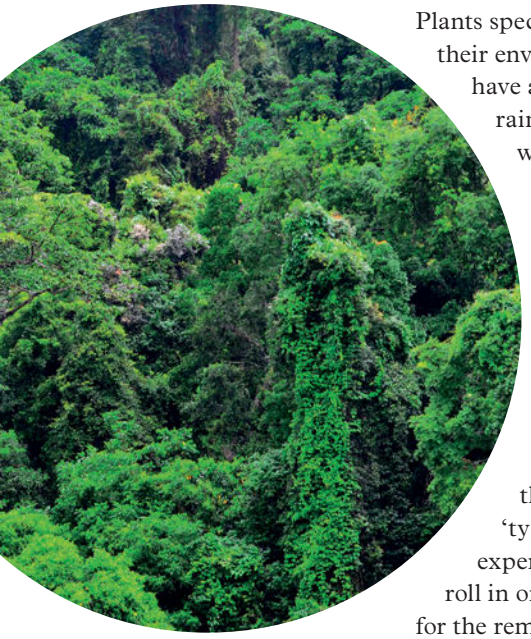


Figure 6 Plants in the Daintree Rainforest are adapted to receive lots of rain.

sclerophyll
a woody plant with evergreen leaves that are tough and thick in order to reduce water loss

evergreen
plants that do not lose their leaves

Australian plant adaptations

Plants species have also adapted to better suit their environment. Many Australian plants have adapted to extreme conditions. In the rainforest, many plants have leaves with waxy leaves and a 'drip tip' on the end that allows water to drain away easily.

Spinifex grass

Spinifex grass is one of the most abundant plants in Australia as it is uniquely adapted to the continent's extremely poor soils and dry conditions. Initially the leaves of the plant appear as 'typical' grass leaves. When the plant experiences its first dry spell, the leaves roll in on themselves and stay that way for the remainder of the plant's life. This adaptation protects the plant from drought by reducing the leaves' surface area exposed to the hot sun and therefore minimising water loss. The leaves have a silvery upper surface that reflects sunlight and also assists in preventing water loss. Spinifex grass has a very deep root system, up to 3 metres below the ground, which allows it to go long periods of time without water.

Eucalyptus, Acacia, Banksias and Grevilleas

Australia is well known for its dry **sclerophyll** forests. Plants in these forests are typically from one of four genera (singular 'genus'): Eucalyptus, Acacia, Banksia and Grevillea. These **evergreen** plants are identified by their woody stems and tough, thick and often spiky leaves. All of these features assist the plants in surviving soils with poor fertility, attack from predators and unpredictable rainfall. Many of these Australian plants are also adapted to survive through times of bushfire. Not only can some survive through extreme fire heat, some plants cannot exist without it. For example, Banksia seeds germinate when they are exposed to the extreme heat of a bushfire. Eucalyptus trees also sprout after fire.



Figure 7 Tufts of spinifex grass growing in the Australian outback



Figure 8 a Eucalyptus tree sprouting after fire in the Blue Mountains; **b** Banksia releasing seeds after a bushfire in Kamay Botany Bay National Park, NSW

Check your learning 10.9

Recall and explain

1 **Define** adaptation.

2 **Identify** the differences between physical and behavioural adaptations. Give an example of each.

3 **Explain** how adaptations help an organism to survive.

Analyse and apply

4 **Propose** how the following adaptations of a bilby could be useful.

- **a** Is nocturnal
- **b** Lives in a burrow
- **c** Has large ears

Evaluate and create

5 **Propose** and **justify** a reason to explain why a species or population with a long life cycle is likely to take much longer to physically adapt to an environmental change than one with a short life cycle.

6 **Investigate** two Australian plants and two Australian animals other than those covered in this topic. Construct a table that includes:

- the organism's classification
- details of the organism's ecosystem
- two adaptations of the organism
- how these adaptations assist in the organism's survival or reproduction.

Skills builder: Questioning and predicting

7 Imagine two birds from the same species. One bird will eat any plant material grown on trees. The other bird will only eat fruit from a tree that depends on good rainfall each year.

- **a** **Predict** which bird is most likely to survive. (THINK: Which bird is more likely to get enough food?)
- **b** **Predict** what will happen to the species. (THINK: What will future generations eat? What do you know about the way species adapt to survive?)

REVIEW

Multiple choice

1 **Identify** a reason for classifying living things.
- **A** Classification helps scientists invent more ways of discussing organisms.
- **B** Classification helps scientists to communicate new discoveries.
- **C** Classification helps scientists to keep new information to themselves.
- **D** Classification helps scientists to shelter living things.

2 Which of the following is an example of a micro-organism?
- **A** Bacteria
- **B** A chicken
- **C** Kelp
- **D** Sand

3 **Identify** which of the following adaptation may help an animal survive in the snow.
- **A** A long tongue
- **B** Big ears
- **C** A long neck
- **D** Thick fur

Recall and explain

4 **Define** the term 'organism'.

5 **Identify** the eight characteristics that all living things share.

6 **Identify** an example of a plant moving by itself.

7 **Describe** the advantages of using a dichotomous key.

8 **Explain** why it is important for scientists to use a common system to group all living things on the Earth.

9 What is a micro-organism? **Explain** using an example.

10 **Compare** vertebrates and invertebrates. Write a definition for each.

11 **Recall** the five main classes of vertebrates and give an example of each.

12 **Recall** at least six phyla of invertebrates and give an example of each.

13 **Explain** how an Australian animal and plant have adapted to better survive in their environment.

Apply and analyse

14 Imagine that an unknown 'thing' was discovered during a space mission and brought back to Earth. Briefly **outline** two different methods that scientists could use to decide whether it was living or non-living.

15 Place the items in the following list in the correct columns in Table 1: stewed apple, iPod, daffodil bulb, DVD, hairs in your brush, your teacher, shark's tooth, germs, soft drink bottle, your pet, silver chain, dinosaur skeleton.

Table 1 Living or non-living?

Living		Non-living
Currently living	Dead	

Evaluate and create

16 One of the main contributors to the *Encyclopedia of Life* is the *Atlas of Living Australia*. Do an internet search for the *Atlas of Living Australia* and click on 'Explore'. From this page you can create a species list and map for the area in which you live.
- **a** What is the most frequently seen animal in your area?
- **b** What is the most frequently seen plant in your area?
- **c** Write a list for each species that identifies the physical characteristics or behaviour that would help them to survive and reproduce.

17 **Examine** Table 2 shows the number of living things on the Earth.

Table 2 Types and numbers of living things on the Earth

Group	Number of species described	Number of species estimated to exist	Total estimated number of living things (%)
Animals with internal backbones (vertebrates)	64 788	80 500	0.7
Animals without a backbone (invertebrates)	1 359 365	6 755 830	61.8
Plants	297 857	390 800	3.6
Fungi	98 998	1 500 000	13.7
Bacteria (Monera)	35 351	>1 200 500	11
Algae and protozoa (Protista)	28 871	>1 000 000	9.2
Total number of species	1 885 230	>10 927 630	100

Source: Chapman, A.D. 2009, *Numbers of Living Species in Australia and the World*, 2nd edn, Australian Biological Resources Study, Canberra.

- **a** How many species of plant are estimated to be on the Earth?

b **Compare** the number of *known* plant species with the total number of *known* animal species (add animals without a backbone and animals with a backbone together). Are you surprised with the result? **Explain**.

18 **Examine** Figure 1. (This can be downloaded from your obook.)

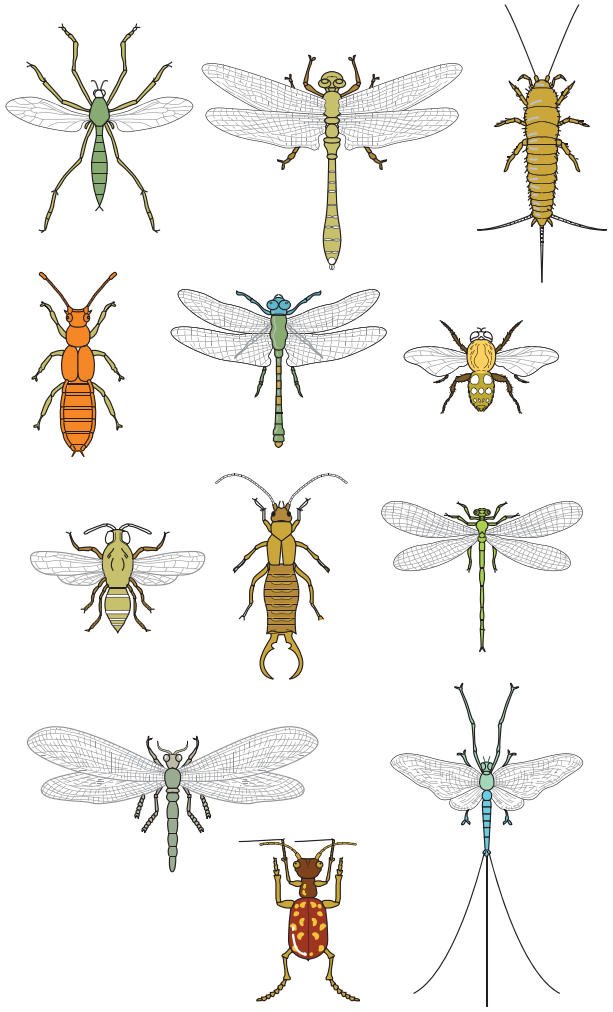


Figure 1 A collection of insects

a Cut out the pictures of the insects so that you can move them around on your desk.

b Working on your own, sort the insects into groups based on some aspect of their appearance. **Justify** your system of classification.

c **Compare** your groupings with those of a partner. Between the two of you, can you think of other ways to classify the insects?

d With your partner, create a dichotomous key for this group of insects.

19 Why was the invention of the microscope important to the development of the classification system? How did it change the number of organisms for identification, classification and communication?

20 You have just returned from a trip to a remote mountain area of the Kimberley, in Western Australia. While there, you took your portable microscope and examined water from a previously unknown lake. To your surprise, you found some new creatures in the water that looked a bit like bacteria. They are single celled and are either square or oval; some are hairy (have hairs either on the end of the cell or along the edge of the whole cell).

a Draw six different versions of these organisms.

b **Construct** a dichotomous key for these six new organisms so that you can describe them to other scientists.

c Name each of the groups at the bottom of your key (you might like to name some of them after yourself).

d Assuming they are a type of bacteria, **classify** them into a kingdom.

21 **Discuss** why monotremes might find it difficult to breed in arid (dry) environments.

Critical thinking

22 Design an experiment to investigate how plants respond to stimuli. Choose one stimulus only (such as reaction to light or to a lack of water) to investigate. This stimulus is the experimental variable, so you will need to change the variable in some way and control the rest of the variables in the experiment. **Identify** the research question, hypothesis, variables and your prediction. Make a list of the equipment you would need.

Going further

23 Figure 2 shows *Elysia chlorotica*, a photosynthetic slug. Early in its life, the slug consumes algae and incorporates the algae's chloroplasts into its own cells. From that point onwards, the slug is able to perform photosynthesis and produce its own food, never eating again. **Evaluate** whether *Elysia chlorotica* should be classified as an animal or a plant.

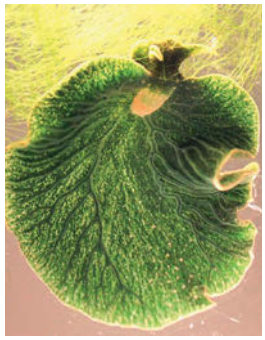


Figure 2 *Elysia chlorotica*

24 Aristotle was one of the first scientists to try to gather information from a wide variety of sources to classify organisms. **Suggest** what method might he have used to tell the differences between a horse and a fly.

Research

25 Choose one of the following topics on which to conduct further research. Present your findings in a format that best fits the information you have found and understandings you have formed.

»A newspaper article

Write a newspaper article about how life on Earth is organised. It needs to be about two pages long (no more than 500 words), and you should explain how living things are classified for an audience that is not familiar with science. Make a list of the living things whose photographs you would like to use to illustrate the article. Try to find their scientific names as well as their common names. Your newspaper article must contain a key of some description.

»Discovering microscopic life

The discovery of micro-organisms is credited to two scientists in the 1600s: Robert Hooke and Antonie van Leeuwenhoek. **Investigate** their role in finding micro-organisms. How they did find them? How did they share their findings? Present your findings as a poster or presentation.

»The water-holding frog

The harsh desert climate of central Australia is most likely the last place you would expect to find an amphibian, given their dependence on water. However, the water-holding frog is able to survive in this very dry environment. Conduct some research on this species of frog to identify the adaptations that help it to survive. Are there are any other species like the water-holding frog? Present your findings as a poster to profile the water-holding frog.



Figure 3 The water-holding frog (*Litoria platcephala*)

Reflect

Now that you've completed this chapter, reflect on your ability to do the following:

	I can do this.	I can't do this yet.
Identify reasons for classifying living things.	☐	☐ Go to page 154–155.
Classify a variety of living things based on similarities and differences in structural features.	☐	☐ Go to page 156–159 and 164–173.
Use simple keys to identify a range of plants and animals.	☐	☐ Go to page 160–161.
Identify some examples of groups of micro-organisms.	☐	☐ Go to page 163–167.
Outline the structural features used to group living things, including plants, animals, fungi and bacteria.	☐	☐ Go to page 164–173.
Explain how the features of some Australian plants and animals are adaptations for survival and reproduction in their environment.	☐	☐ Go to page 174–177.

Source: NSW Science Years 7–10 Syllabus © NSW Education Standards Authority for and on behalf of the Crown in right of the State of New South Wales, 2018.

CELLS

How do the structure and function of cells differ between organisms?

11

Have you ever wondered ...

- Do plants and animals have the same types of cells?
- How do we know cells exist if they're so small?
- Where do cells come from?

SCIENCE UNDERSTANDING

In this chapter you will learn how to:

- identify that living things are made of cells
- identify structures within cells, including the nucleus, cytoplasm, cell membrane, cell wall and chloroplast, and describe their functions
- outline the role of respiration in providing energy for the activities of cells
- identify that new cells are produced by cell division
- distinguish between unicellular and multicellular organisms
- identify that different types of cells make up the tissues, organs and organ systems of multicellular organisms.

Source: NSW Science Years 7–10 Syllabus © NSW Education Standards Authority for and on behalf of the Crown in right of the State of New South Wales, 2018.

Check your Student obook assess for these digital resources and more:

QuizletLive
Compete in teams to test your knowledge.

Assess quiz
Before you start this chapter, assess your science skills.

Check your Teacher obook assess for these digital resources and more:

QuizletLive
Launch a quiz for your students on key concepts in this chapter.

11.1 All living things are made up of cells

In this topic you will learn that:

- cells are the smallest units of life
- all cells originate from other cells.

cell
(in biology) the building block of living things

microbiology
the science involving the study of microscopic organisms

cell theory
the theory that all organisms are composed of one or more cells; cells are the basic unit of life, and new cells are created from existing cells

single-celled
consisting of one cell

microbe
a living thing that can only be seen with the use of a microscope; a micro-organism

Scientists have not always known that living things are made up of cells. It was the invention of the microscope in the mid-17th century that allowed us to see the building blocks of life – the tiny units that form every living thing. Microscopes showed that each and every living thing is made up of **cells**.

Discovering cells

When English physicist Robert Hooke (1635–1703) published his book *Micrographia* in 1665 it became a bestseller. Hooke had made one of the first microscopes. With it, he observed many types of living things and made accurate drawings of what he saw.

Hooke's most famous achievement was his diagram of very thin slices of cork (see Figure 1). He was surprised to see that, under the microscope, the cork looked like a piece of honeycomb. He described the 'holes' and their boundaries in the 'honeycomb' as cells because they reminded him of the small rooms in a monastery, which are also called cells.

Hooke had discovered plant cells. Although some called *Micrographia* 'the most ingenious book ever', others ridiculed Hooke for spending so much time and money on 'trifling pursuits'. Thankfully for us, and for the whole science of **microbiology**, Hooke ignored the taunts and kept experimenting with microscopes. It was because of Hooke's contribution to microbiology that other scientists went on to develop a further understanding of cells.

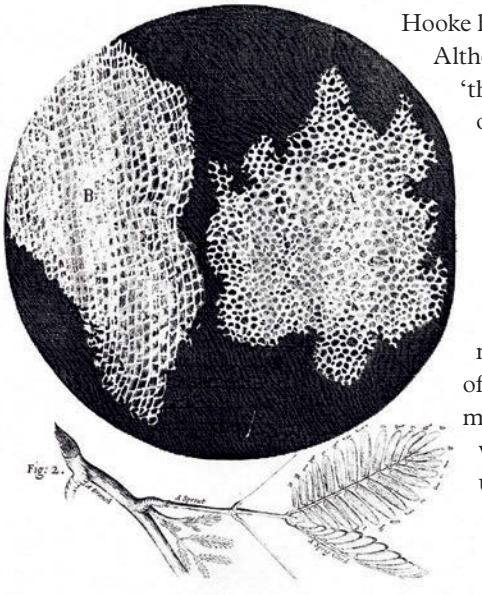


Figure 1 Robert Hooke's drawing of cork

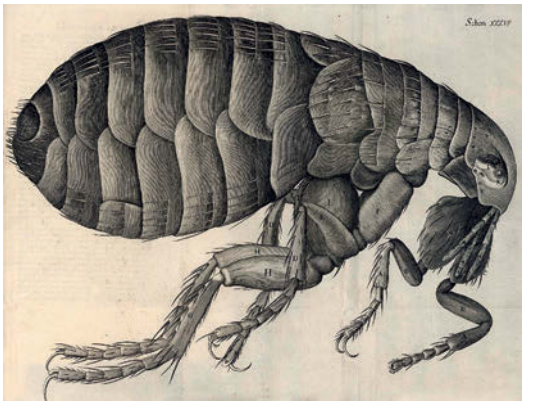


Figure 2 Robert Hooke's detailed drawing of a flea

Cell theory

Cell theory describes the properties of cells and their role in living things. It was first proposed in 1839 by German biologists Theodor Schwann (1810–1882) and Matthias Schleiden (1804–1881). In 1858, German pathologist Rudolf Virchow (1821–1902) concluded the final part of the classic cell theory. The combined cell theory included the following principles:

- All organisms are composed of one or more cells.
- Cells form the basis of every living structure.
- New cells are created from existing cells.

Any living thing that has more than one cell is referred to as multicellular, but there are many living things, such as bacteria, that consist of only one cell. These are called **single-celled** or unicellular organisms. Micro-organisms, which are also often referred to as **microbes**, are organisms that can only be seen under the microscope – they can be single-celled or multicellular.

SKILLS LAB

11.1: Drawing cells
Go to page **378**.

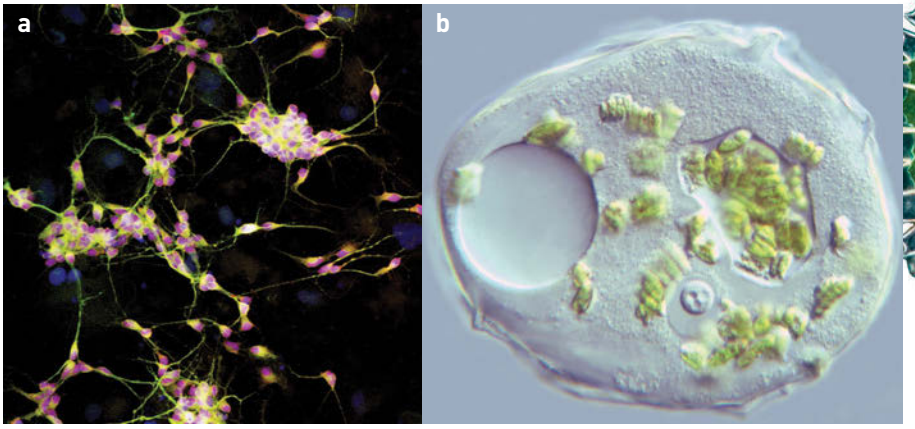


Figure 3 a Human nerve cells are part of multicellular humans. **b** The amoeba is a unicellular organism.

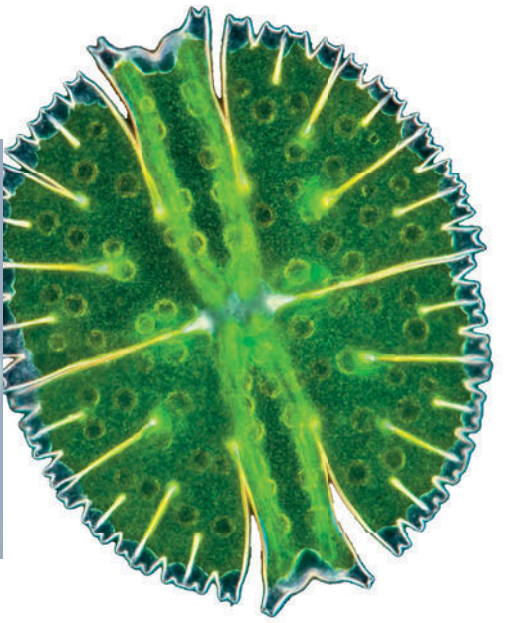


Figure 4 The irregular shape of this unicellular organism (called a desmid) maximises the surface area to volume ratio.

Why are cells so small?

The surface of a cell is called the cell membrane. Some substances can move across this membrane: **nutrients** enter the cell and wastes exit it. In order to survive, cells benefit from the relatively large surface area of the cell membrane to maximise the ability to take in nutrients and remove wastes through the membrane.

The total space inside the cell is referred to as the cell's volume. As a cell increases in size, both its volume and its surface area increase. The problem with this is that for every small increase in size, the volume increases much more than the surface area. Eventually the volume becomes so big that it becomes difficult for nutrients to move into the centre of the cell and for wastes to be removed. We compare the relationship between the amount of surface area and the volume of a cell through a fraction – the **surface area to volume ratio**. Small cells have a large surface area compared with their volume (a large surface area to volume ratio) and are therefore better able to survive.

This explains why single-celled organisms are so small. A single cell must do all the same things that a larger organism does. The cell membrane is particularly important because it provides a barrier between the inside of the cell and the external environment. All the nutrients needed to keep the cells alive, and the waste products made by the cell, are transported across the cell membrane. It is essential that the cell membrane provides a large surface area for the transport of so many molecules into and out of the cell.

nutrient
a soluble substance that an organism needs to live and grow; usually taken in from the environment

surface area to volume ratio
the relationship between the area around the outside of a cell and its volume as a fraction

Check your learning 11.1

Recall and explain

1 **Identify** the scientists who used one of the first microscopes to observe cork cells.
2 **Recall** the three principles of the combined cell theory.
3 **Distinguish** between the terms 'unicellular' and 'multicellular'. Provide two examples of each.
4 **Summarise** what all unicellular organisms have in common.

Apply and analyse

5 **Predict** what would happen if a cell increased its surface area to volume ratio.
6 **Assess** the contribution that the discovery of the microscope has made to our understanding of living things.

Evaluate and create

7 The common house dust mite is a micro-organism. Could you see this animal without a microscope? **Justify** how you came to your answer.

Skills builder

8 **Construct** a scaled timeline to show the contribution of different scientists to the cell theory. (THINK: What information do you need to include to help someone understand the development of cell theory over time?)

11.2 Microscopes are used to study cells

In this topic you will learn:

- about different types of microscopes
- how to use a light microscope.

microscope
a scientific instrument used to magnify the apparent size of an object

electron microscope
a microscope that uses electrons (tiny negatively charged particles) to create images

stereomicroscope
a microscope with two eyepieces that uses low magnification

compound light microscope
a microscope with two or more lenses

eyepiece
lens where the eye is placed when using a microscope

objective lens
the lens closest to the specimen



Figure 1 Scanning electron microscope (SEM) image of a nerve cell

In the same way that eyeglasses have a glass or plastic lens for vision correction, a **microscope** is an instrument that uses lenses to magnify the size of the object placed under it. Over time their magnifying ability has improved and continues to do so. This has made it possible to study cells.

Types of microscopes

As a science student, you will have the opportunity to use a light microscope in your laboratory to observe a range of different cells. You may also see images produced by **electron microscopes**.

Light microscopes

There are two common types of light microscope – the **stereomicroscope** and the **compound light microscope**. The stereomicroscope is used for viewing larger objects, such as insects (see Figure 2). It can magnify up to 200 times and shows a three-dimensional view. The compound light microscope is used to observe thin slices of specimens (see Figure 3). It can magnify up to 1500 times. Its view is two dimensional. The specimen must be thin enough to allow light to pass through it.

The stereomicroscope has two **eyepieces** to look through, whereas the compound light microscope can have one or two eyepieces. The word 'monocular' is used to describe a microscope with one eyepiece (*mono* means 'one'). Microscopes with two lenses are called binocular (*bi* means 'two'). The compound light microscope uses the effect of two lenses (the lens in the eyepiece and the **objective lens** further down the column) combined with light to give a greater magnification. A stain, such as iodine, is often used to provide contrast, making the cells or microscopic organism easier to see (see Figure 5).

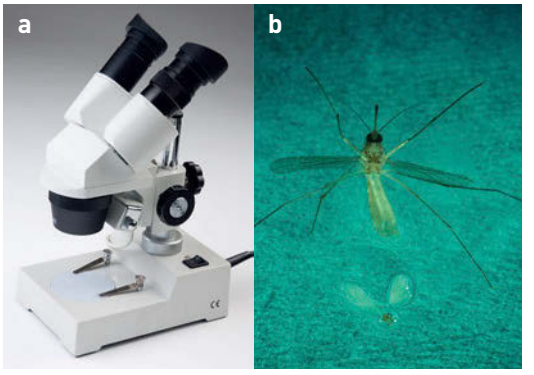


Figure 2 a A stereomicroscope; **b** an insect, as seen under a stereomicroscope

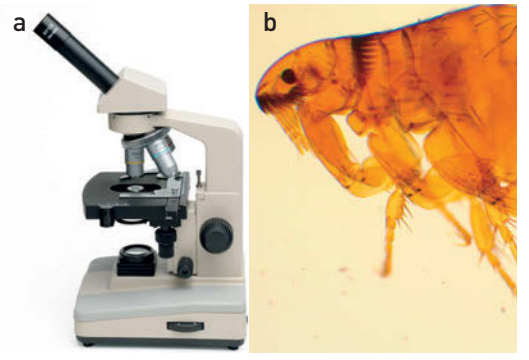


Figure 3 a A compound light microscope; **b** a flea as seen under a compound light microscope

Electron microscopes

Electron microscopes use electrons (tiny negatively charged particles) to create images. The first electron microscope, the transmission electron microscope (TEM), was invented in 1933. The scanning electron microscope (SEM), which was developed later in 1937, uses a beam of electrons to scan across a specimen showing details of its surface.

Electron microscopes can magnify up to a million times. Using this technology, scientists are able to view cells in more detail.

Getting to know your compound light microscope

Figure 4 shows the parts of a monocular compound light microscope. Microscopes are fragile instruments that must be treated with care.

- Always use two hands to carry a microscope – one hand around the main part of the instrument and the other underneath it.
- Some microscopes have a built-in lamp, whereas others have separate lamps that need to be set up so that they shine onto the mirror. Adjust the mirror to project the light through the stage onto the specimen. Do not allow sunlight to shine directly up the column.
- Place the slide on the stage and select the objective lens with lowest magnification.
- Look from the side and adjust the coarse focus knob so that the objective lens is just above – and not touching – the slide. Check which way you must turn the knob to move the objective lens away from the slide.
- Use the coarse focus knob to bring the specimen into view. Use the fine focus knob to help you see it more clearly.
- If you want a higher magnification, rotate the objective lens to a higher magnification.
- Draw what you see (as a record) using a pencil.
- Work out the total magnification.
- Write the magnification next to your sketch.
- Label and date the sketch.

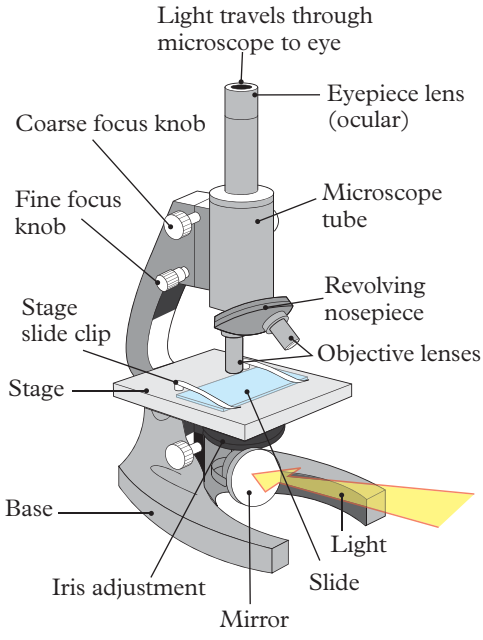


Figure 4 Parts of a compound light microscope

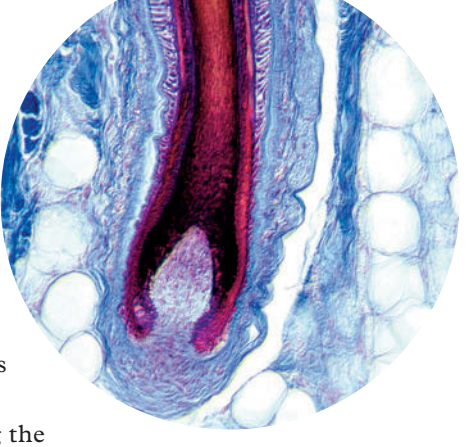


Figure 5 Human hair root that is stained for contrast.

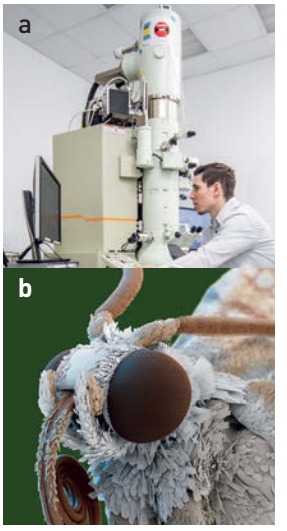


Figure 6 a An electron microscope; **b** a moth proboscis

Magnification calculations

Using different combinations of lenses means you can magnify your object by different amounts. To calculate the total magnification of a compound light microscope, multiply the magnification of the eyepiece lens by the magnification of the objective lens. These figures are marked on each lens.

Table 1 The total magnification of a microscope can be determined by multiplying the magnifications of the eyepiece and the objective lens.

Eyepiece magnification	Objective lens magnification	Total magnification
× 5	× 10	× 50
× 10	× 20	× 200

Video
Microscope skills

Check your learning 11.2

Recall and explain

1 **Identify** the type or types of microscopes that are in your science laboratory.

2 **Explain** why very thin samples must be used under a light microscope.

3 **Identify** three reasons why it is important to label and date your specimen drawings.

Skills builder: Processing and analysing information

4 Complete the following magnification table for a compound light microscope. (THINK: magnification can be calculated by multiplying the eyepiece and objective magnification.)

Eyepiece magnification	Objective lens magnification	Total magnification
× 5		× 100
	× 20	× 300
× 10	× 50	

11.3 Plant and animal cells have organelles

In this topic you will learn that:

- organelles are mini-organs that allow a cell to function
- cellular respiration takes place in the mitochondria and provides energy for all life functions.

organelle
a smaller part of a cell, each having a different function

DNA
a molecule that contains all the instructions for every job performed by the cell; this information can be passed from one generation to the next

cell membrane
the barrier around a cell that controls the entry and exit of substances into and out of a cell

cytoplasm
the 'jelly-like' fluid inside the cell membrane that contains dissolved nutrients, waste products and organelles

A cell is the basic unit of life. It is called this because it is the smallest unit of an organism that is considered living. But, just as a car can be broken down into smaller parts that work together, the cell is made up of smaller parts, too. Cells are made up of **organelles** (mini-organs), cytoplasm, DNA, nutrients, wastes and other substances.

Cell structures

All cells, regardless of which type of organism they are found in, share the same basic structure. This basic structure includes three key features:

- **Cell membrane**: This acts like the 'skin' of a cell, forming a barrier around it. The cell membrane controls the entry and exit of material into and out of the cell.
- **Cytoplasm**: This is the jelly-like fluid inside the cell membrane that surrounds everything inside the cell. It helps provide structure to the cell and contains many dissolved nutrients and waste products.
- **DNA**: (deoxyribonucleic acid): This contains the instructions for every job your cells need to do and is passed from one generation to the next. The same complete set of DNA is found in every one of your cells (with a few exceptions).

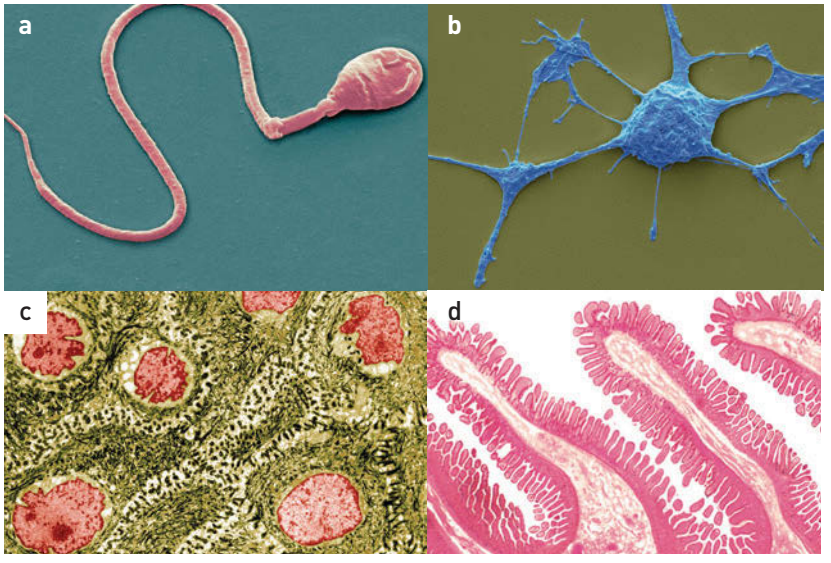


Figure 1 Cells can be different shapes and sizes: **a** sperm cell, **b** nerve cell, **c** skin cells, **d** intestinal cells.

A closer look at organelles

Each type of organelle in a cell has a specific function. These functions are necessary for the cell to survive. But not all cells have the same organelles. For example, some cells do not have a nucleus. We will learn more about these cells in the next topic.

Nucleus

The **nucleus** is often called the control centre of the cell. It contains the DNA of a cell and coordinates the cell's activities. The nucleus is surrounded by a nuclear membrane to separate it from the rest of the cell.

Chloroplasts

Chloroplasts are only found in plant cells and some unicellular organisms. These organelles are like microscopic solar panels that transform solar energy into chemical energy.

Chloroplasts are usually green because of a molecule called **chlorophyll**. Chlorophyll uses the Sun's light energy to rearrange molecules of carbon dioxide and water into glucose and oxygen. This chemical reaction is called **photosynthesis**. Plants will then use the glucose produced during photosynthesis to release energy in their own mitochondria.

CHALLENGE
11.3: Comparing the size of cells and their parts
Go to page **380**.

INVESTIGATION
11.3A: Looking at organelles
11.3B: Measuring cells
Go to page **381**.

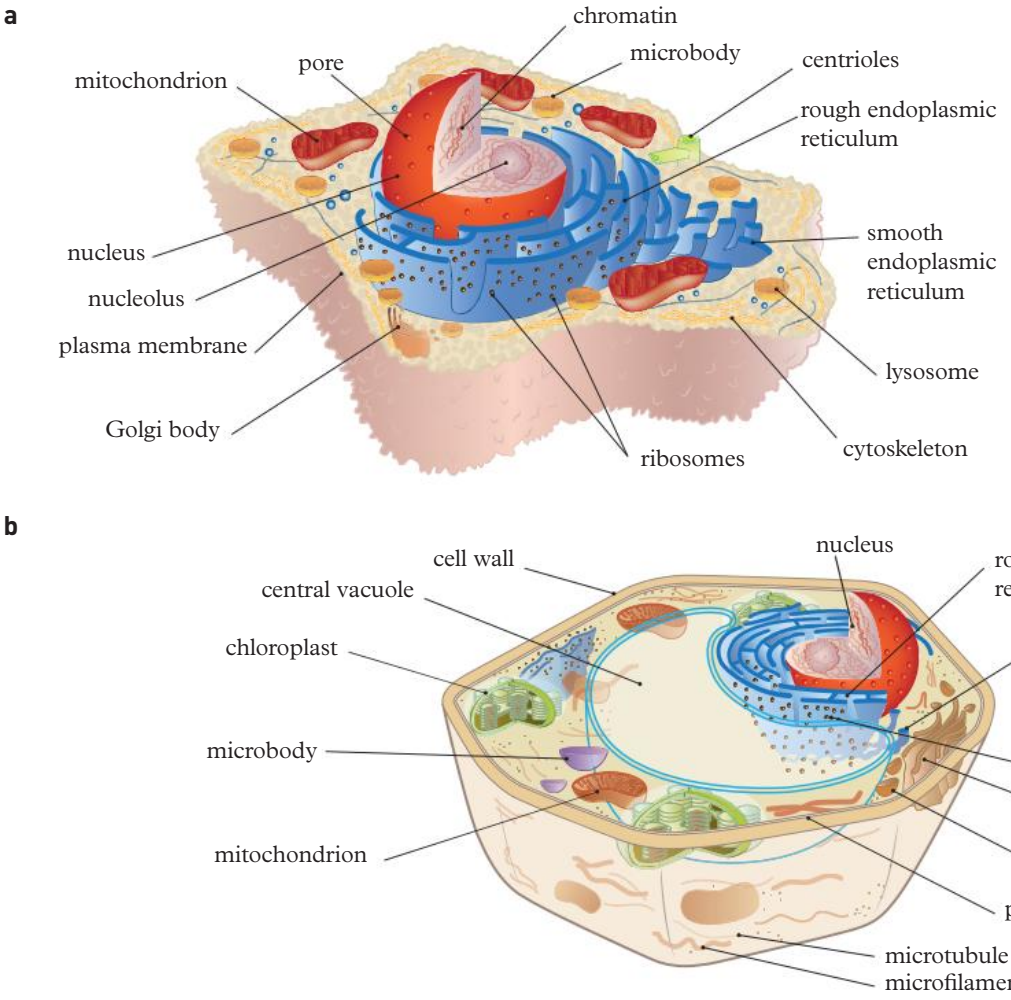


Figure 2 Some key structures of **a** animal cell, **b** plant cell and **c** bacterial cell

Interactive
Plant cell

Cell wall

The **cell wall** (Figure 2) is a layer surrounding the cell membrane of the cells in many organisms. Animal cells do not have a cell wall. The cell wall is a very important structure in plant cells, as it provides structure to the cell and in turn the plant.

Vesicles

Vesicles are organelles that are used by plant and animal cells to store water, nutrients and waste products. A membrane surrounds the vesicle, separating the substances from the rest of the cell. Plant cells usually have one large vesicle called a vacuole that helps to provide support and structure to the cell, which in turn assists the plants in growing upright and displaying their leaves to the Sun (see Figure 2). Animal cells may have many small vesicles.

nucleus
the control centre of a cell that contains all the genetic material (DNA) for that cell

chloroplast
an organelle found in plant cells that transforms solar energy into chemical energy

chlorophyll
the green pigment found inside chloroplasts that absorbs solar energy and uses it in photosynthesis

photosynthesis
the chemical process plants use to convert glucose and oxygen from carbon dioxide and water

cell wall
a structure that provides support around some cells

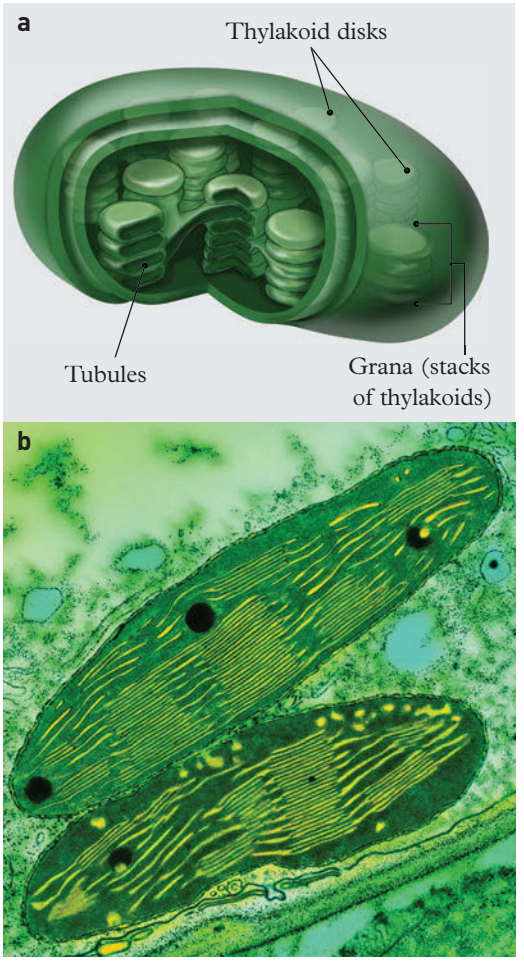


Figure 3 a A schematic diagram showing the structure of a chloroplast; **b** an electron micrograph of a chloroplast

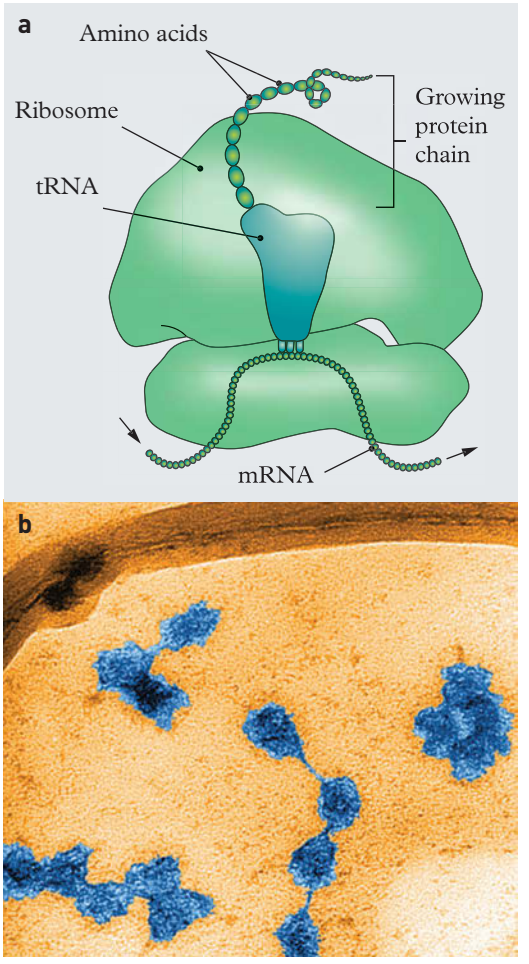


Figure 4 a A schematic diagram showing the structure of a ribosome; **b** an electron micrograph of ribosomes

ribosome
a cell structure where protein production takes place

cellular respiration
the chemical process where sugars (glucose) and oxygen are converted into carbon dioxide, water and energy

mitochondrion
the powerhouse organelle of a cell; site of cellular respiration (energy production) (plural *mitochondria*)

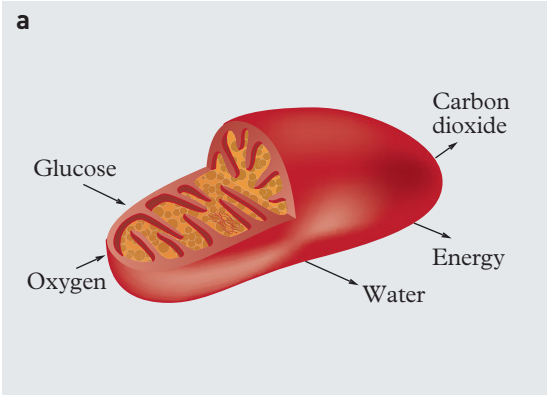
Ribosomes

Ribosomes are the site of protein production in cells. Proteins are small molecules each with a different role. Types of proteins include structural proteins (such as those found in hair and nails) and globular proteins (such as haemoglobin, which is found in red blood cells and helps transport oxygen through the bloodstream). Other proteins are involved in chemical reactions and also form part of the cell's own structure.

Cellular respiration in the mitochondria

Mitochondria (singular 'mitochondrion') are the powerhouse of the cell – the site of energy production in the cell. There may be several thousand mitochondria in a cell depending on the role of the cell. For example, skeletal muscle cells contain a lot of mitochondria to make sure we have enough energy to run and jump when we need to.

Mitochondria are rod-shaped organelles with an inner and an outer membrane. The inner membrane is folded to increase the surface area of the membrane. A chemical reaction called **cellular respiration** occurs inside the mitochondria. This reaction involves the rearrangement of the atoms in glucose (a sugar from the food we eat) and oxygen (from the air we breathe) to release water, carbon dioxide and energy. This energy is used by our bodies to help us perform all life functions. Remember: MR N GREWW (see chapter 10). Without cellular respiration, no living thing could survive.



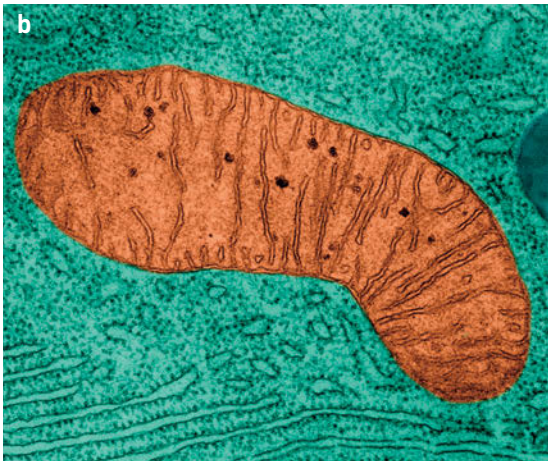


Figure 5 a Cellular respiration takes place in the mitochondria where glucose and oxygen are converted into carbon dioxide, water and energy. **b** An electron micrograph of a mitochondrion

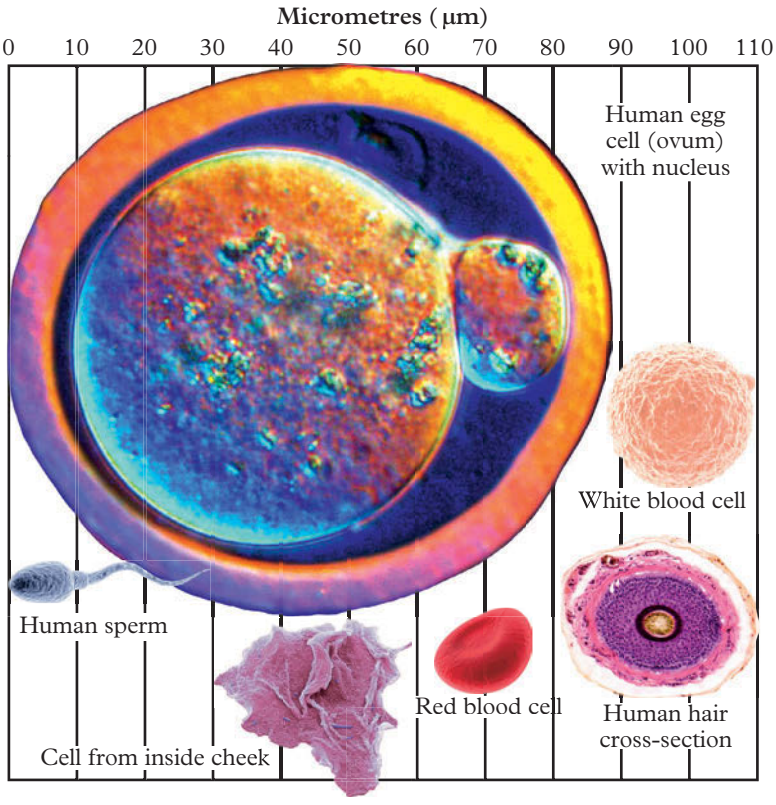


Figure 6 Different types of cells are different sizes and are measured in micrometres (μm). One micrometre is equivalent to one-thousandth of 1 millimetre.

Check your learning 11.3

Recall and explain

1 **Describe** the function of the following.
   - a Nucleus
   - b Cytoplasm
   - c Cell membrane
   - d Cell wall
   - e Chloroplast

2 **Identify** the organelle where cellular respiration occurs.

3 **Summarise** the process of cellular respiration.

Apply and analyse

4 **Outline** the features of cells that mean they are classified as living things. (Hint: Remember MR N GREWW.)

5 **Examine** the image in Figure 7. Is it an animal or a plant cell? **Explain** your reasoning.

Evaluate and create

6 **Construct** a table that compares and contrasts the organelles and other structures of animal and plant cells.

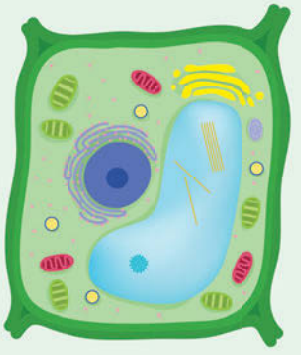


Figure 7 Animal or plant cell?

Skills builder: Questioning and predicting

7 In a multicellular organism, **predict** which of the following cells would have the most mitochondria: bone cells, muscle cells or hair cells. **Justify** your reasons. (THINK: What is the function of mitochondria?)

11.4 Organisms can be classified as prokaryotic or eukaryotic

In this topic you will learn that:

- cells are classified into two main groups – prokaryotic cells and eukaryotic cells
- unicellular organisms consist of either prokaryotic cells or eukaryotic cells
- all multicellular organisms have eukaryotic cells.

Unicellular (*uni* means 'one') organisms perform all of life's functions on their own. They are also called micro-organisms or microbes because they are often only visible through a microscope. Multicellular (*multi* means 'many') organisms are made up of many cells all working together to meet the needs of the organism. An organism's cell type can be used to classify it. Cells are classified into two main groups – prokaryotic cells and eukaryotic cells.

natural flora
microbes that live happily in or on our bodies

prokaryotic cell
a primitive single-celled organism that has no nucleus

pathogen
a microbe that can potentially cause a disease

infectious disease
a disease caused by the passing of a pathogen from one organism to another; also known as contagious disease

symptom
a change that occurs to an individual as a consequence of a disease

Prokaryotic cells

Prokaryotic cells are the most primitive cellular forms on Earth and are unicellular. They are much simpler than eukaryotic cells and by definition they do not have membrane enclosed organelles. For example, they have no nucleus and their genetic material is found free floating in the cytoplasm.

Unicellular organisms, such as bacteria, are living in and around us all the time.

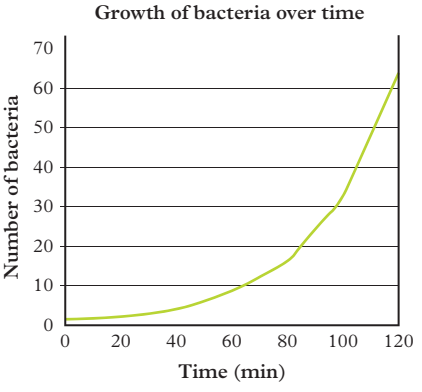


Figure 1 The number of bacteria cells can double every 20 minutes.

The average adult human has 1 kilogram of non-human life inside their large intestine alone. Some bacteria and microbes are essential for keeping our body healthy and working correctly. Others can be deadly.

Natural flora

The unicellular microbes that live happily in, and on, our bodies are referred to as **natural flora**. The correct balance between natural flora and the microbes in our environment is important to our health. The right amount of natural flora will protect us against foreign invaders, whereas too much of the natural flora can actually make us ill. Bacteria in our intestines help our bodies digest food and provide vitamins to keep us healthy. The bacteria on our skin acts as a protective coating, preventing disease-causing bacteria from growing.

Disease-causing microbes

We have all been sick at some stage in our lives. Some diseases that make us sick are caused by pathogens. A **pathogen** is a micro-organism that can potentially cause a disease. With **infectious diseases**, the pathogen may be passed from one organism to another. Such diseases are said to be contagious. The host is an organism, such as a human, animal or plant, on which another organism lives. You will be investigating pathogens in more detail in Year 9. The **symptoms** of a disease are the changes that occur to an individual as a consequence of the disease.

Bacteria cause diseases such as tuberculosis (also known as TB), pneumonia, legionnaires' disease and cholera. Bacteria can also be beneficial, as we will learn more in chapter 14.

CHALLENGE **11.4:** Classifying using cells
Go to your obook.

INVESTIGATION **11.4:** Plant and animal cells
Go to page **382**

Part of the success of disease-causing bacteria is due to their relatively simple cell structure and genetics, and their ability for fast growth. Bacteria reproduce using a process called **binary fission** (*binary* means 'two'; *fission* means 'split'). As the name suggests, a bacteria cell grows slightly larger and then splits in two. This is a very quick process, sometimes taking as little as 20 minutes to complete. This can be represented on a graph such as the one in Figure 1. As a result, it can be quite difficult to treat bacterial diseases.

Eukaryotic cells

Eukaryotic cells are more complex. Eukaryotic cells have membrane-bound organelles, which include the nucleus, mitochondria, chloroplasts and vesicles. An organism that consists of eukaryotic cells is referred to as a eukaryote. Eukaryotes can be either unicellular or multicellular.

Plant cells

All true plants are multicellular eukaryotes. By looking at different characteristics of plants and animals, it's fairly easy to see that they are different types of organisms. However, once microscopes started to become more powerful, suddenly scientists could see that there were differences between plant and animal cells (see Figure 3). Plant cells use their chloroplasts to photosynthesise and need cell walls to provide structure. Many plant cells also store their nutrients in large **vacuoles** (large spaces surrounded by a membrane).

Animal cells

Like plants, all animals are multicellular eukaryotes made of more than one cell and often many billions of cells. The different cells in a multicellular organism communicate and work together to produce a functioning organism. Their different roles in the body mean they have different sizes and shapes.

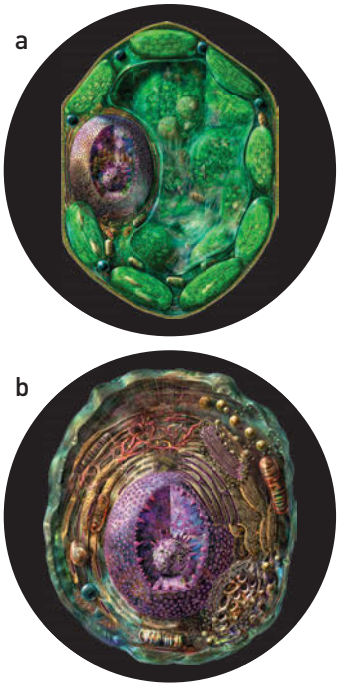


Figure 3 Typical **a** plant and **b** animal cells

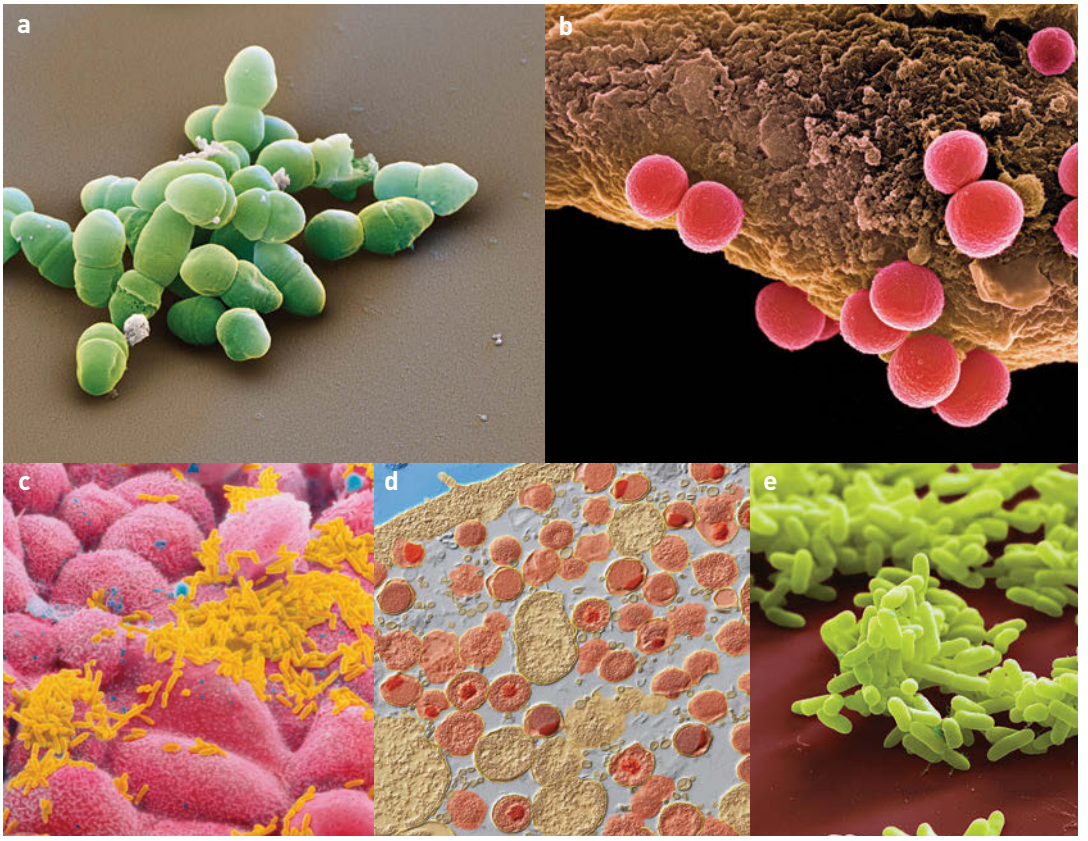


Figure 2 Bacteria under electron microscope: **a** *Staphylococcus epidermis*; **b** *Staphylococcus aureus* in the hair; **c** *Haemophilus influenza* in the nose; **d** *Chlamydia trachamates* in the eye; **e** *Eschaerichia coli* in the intestines

binary fission
a form of asexual reproduction used by bacteria; the splitting of a parent cell into two equal daughter cells

eukaryotic cell
a complex cell that contains a nucleus and membrane-bound organelles

vacuole
a large fluid-containing space or vesicle, a membrane-bound organelle in a cell

Fungal cells

While all fungi are eukaryotes, they can be unicellular (such as yeast), or multicellular. Fungi were originally classified as types of plants; however, with the development of the microscope, scientists were able to see that fungal cells were not the same as plant cells at all. For example, fungal cells don't have chloroplasts, so they cannot photosynthesise; they also lack large vacuoles filled with liquid.

Protists

Protists are a diverse group of organisms. All are eukaryotes and while most are unicellular, there are some multicellular protists. Many live in water, some are photosynthetic (that is, make their own food, like plants), some consume other organisms and some cause diseases. Malaria, one of the world's biggest killers, is caused by a protist that is transferred to humans via a mosquito bite. Depending on where it lives and its food sources, a protist's shape or structure will have evolved to suit. The protists in Figures 5–8 have structures particular to their lifestyles.

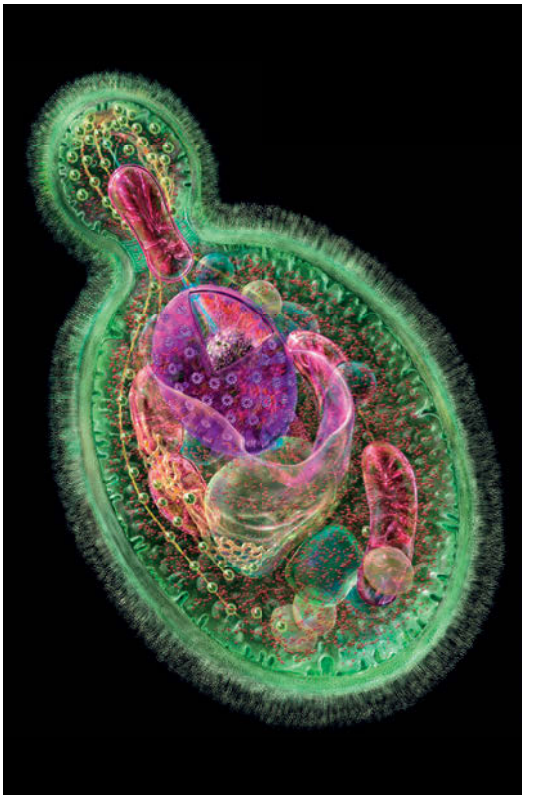


Figure 4 Cells in Kingdom Fungi have cell walls and nuclei, but no chloroplasts.

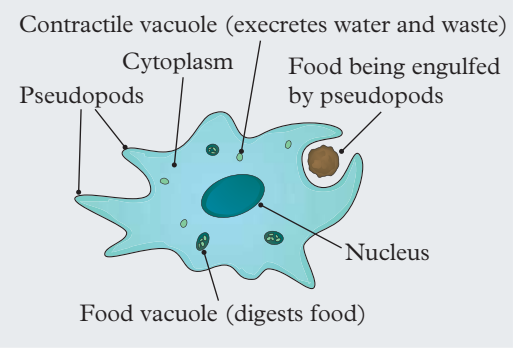


Figure 5 An amoeba can change the shape of its blobby body, creating foot shapes for movement and mouth shapes for swallowing food.

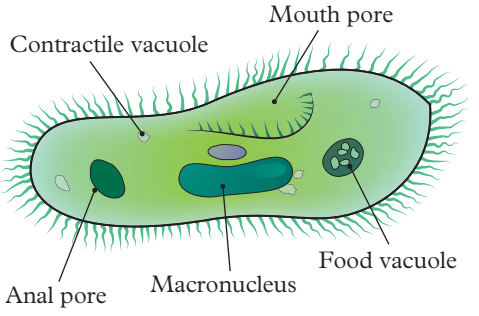


Figure 7 The paramecium plods along slowly with lots of tiny hairs called cilia that act like miniature oars.

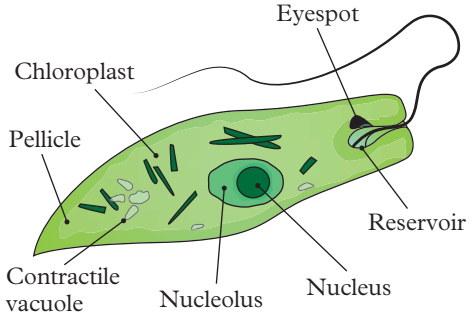


Figure 6 Euglena moves really quickly when it needs to, with a bullet-shaped body and a long tail called a flagellum to whip it into action.

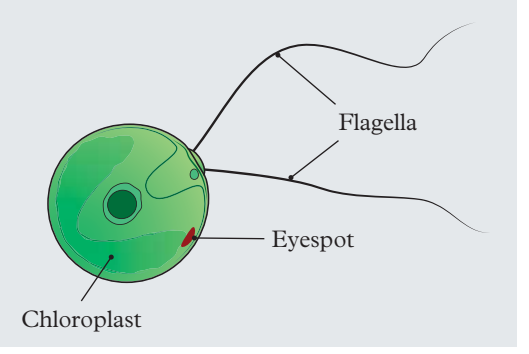


Figure 8 Chlamydomonas has an eyespot that can detect light for photosynthesis and two flagella that help it swim along in a breaststroke-like motion.

Comparison of eukaryotes and prokaryotes

Table 1 Characteristics of eukaryotic and prokaryotic cells

Characteristic	Kingdom				
	Eukaryotes			Prokaryotes	
	Animals	Plants	Fungi	Protists	Bacteria
Number of cells	Multicellular	Multicellular	Multicellular, some unicellular (e.g. yeasts)	Multicellular or unicellular	Unicellular
Cell wall	Absent	Present	Present	Present in some	Present in some
Genetic material	Present	Present	Present	Present	Present
Nucleus	Present	Present	Present	Present	Absent
Mitochondria	Present	Present	Present	Present	Absent
Chloroplasts	Absent	Present	Absent	Present in some	Absent
Large vacuoles	Absent	Present	Absent	Present in some	Absent
Ribosomes	Present	Present	Present	Present	Present

Check your learning 11.4

Recall and explain

1 **Identify** an example of a unicellular organism and a multicellular organism.

2 **Describe** the two main differences between prokaryotic and eukaryotic organisms.

3 **Identify** the type of micro-organism our digestive system relies on and **outline** what this organism does.

Apply and analyse

4 Table 1 shows that plant cells contain chloroplasts. Although a typical plant cell contains chloroplasts, chloroplasts are not found in all plant cells.

- a **Propose** why some cells in a plant root may lack chloroplasts.
- b **Identify** which part of a plant you would expect cells to contain many chloroplasts.

5 Look back at Table 1, and then **propose** which kingdom is often referred to as 'the rest'.

Evaluate and create

6 *Clostridium perfringens* is a species of bacteria that can cause food poisoning. It is one of the fastest-growing bacteria, with a new generation created every 10 minutes.

- a Assuming that you started with a population of two cells, **construct** a graph that shows the population growth of *Clostridium perfringens* over a three-hour period.
- b If the bacteria was grown under controlled conditions, where no additional nutrients were added, **explain** how the shape of the graph would change over time.
- c It is not recommended that food be left out of the fridge for more than three hours. Use the information in the graph and your knowledge of binary fission to **explain** why.

Skills builder: Planning investigations

7 Hayley wanted to compare fungal cells to plant cells under the microscope. **Identify** a list of equipment Hayley would need to conduct this investigation and **outline** a step-by-step method she should use. (THINK: What does Hayley need to do step by step? Think through what equipment she would need at each phase.)

11.5 New cells are produced by cell division

In this topic you will learn that:

- all cells originate from other cells through a process of cell division called mitosis or meiosis.

fertilisation
stage of sexual reproduction involving the joining of gametes

meiosis
a type of cell division that produces specialised sex cells

Cells, like organisms, need to carry out many functions to survive. They need to process many substances, harness energy and, ultimately, reproduce. The instructions for each of these tasks are found in the DNA of each cell.

Where do cells come from?

The cell theory states that all cells are created from existing cells. The process by which this occurs is called cell division. There are three main types of cell division, which will be explored in greater detail in chapter 12: **mitosis**, meiosis and binary fission.

mitosis
a type of cell division that produces identical daughter cells for growth or repair

DNA
a molecule that contains all the genetic instructions of an organism; this information can be passed from one generation to the next

daughter cell
a cell that results from parent cell division

The main type of cell division occurring in humans is mitosis. You started as a single cell that contained all your genetic information (**DNA**). The billions of cells that you are now made of, each containing the same DNA, can be traced back to that one original cell. That single cell divided into two, the two into four, the four into eight and so on. If it was this simple though, each cell division would result in **daughter cells** with only half the required amount of DNA. When cells are ready to divide, the DNA in the cell doubles in a process called DNA replication. This produces two exact copies of the DNA so that each daughter cell can have its own copy. Many of the organelles are also replicated and divided evenly between the daughter cells. When mitosis occurs in multicellular organisms, it is for growth and repair.

Prokaryotic organisms reproduce (produce new organisms) with a very similar type of cell division called binary fission.

In sexually reproducing organisms, an individual inherits half of its DNA from its mother and half from the father through a process called **fertilisation**. **Meiosis**, the third type of cell division, is responsible for the production of the specialised sex cells involved in fertilisation: eggs, sperm and pollen. This ensures that each individual of the same species has the same amount of genetic information.

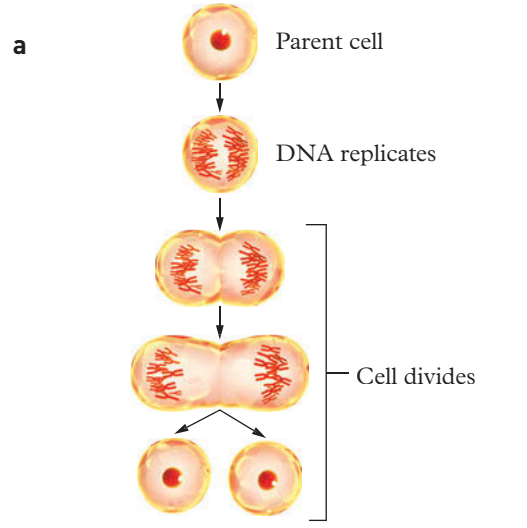


Figure 1 Cell division: **a** diagrammatic representation of mitosis; **b** plant cells at various stages of mitosis

CHALLENGE
11.5: Modelling mitosis
Go to page **383**.

Cancer: Cell division out of control

Cells do not survive indefinitely within an organism. They have a use-by date, after which they self-destruct in a process called apoptosis. This ensures that cell division is controlled.

The term **cancer** describes a group of diseases that result from uncontrolled cell division. A cancer can form in any part of the body and affects humans and other animals.

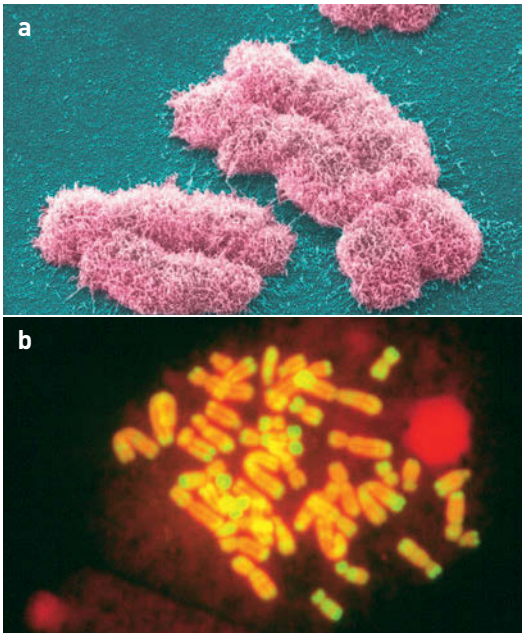


Figure 2 a Light microscope and **b** electron microscope images of DNA replicating and dividing into cells

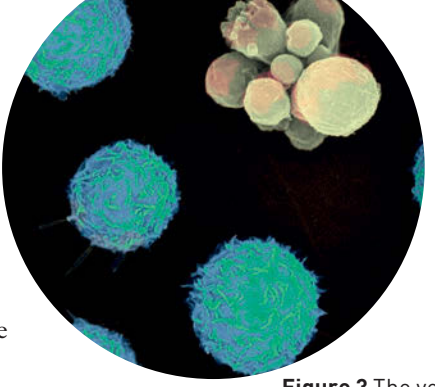


Figure 3 The yellow cell is undergoing apoptosis, or programmed cell death.

As an organism grows, cells reproduce to replace cells that are old or those that have died through injury. The process of a cell dying is a very normal and important part of the development and functioning of an organism. Programmed cell death is known as apoptosis.

Sometimes the DNA of a cell becomes damaged. This may be caused by a number of things, such as radiation, viruses or chemicals, which are called **mutagens**. Cancer-causing substances are called **carcinogens**. The change to the DNA results in a change in the instructions for the cell.

Damage to the genetic material may prevent a cell from self-destructing. When a damaged cell starts dividing uncontrollably, it is called a growth or tumour. The **tumour** is the cancer. The tumour may split off and spread throughout the body, causing secondary cancers. The secondary cancers can damage or destroy other organs.

There are two types of tumours: benign and malignant. Benign tumours do not spread and are not normally fatal (causing death), unless they grow in a vital organ such as the brain. In contrast, malignant tumours can spread to different parts of the body and can be fatal if their growth is not stopped.



Figure 4 Tasmanian devil face tumour is a malignant tumour.

cancer
a group of diseases that result from uncontrolled cell division

mutagen
a substance that may damage a cell's genetic material (DNA)

carcinogen
a cancer-causing substance

tumour
a growth or lump caused by a cell growing out of control

Check your learning 11.5

Recall and explain

1 **Explain** why new cells need to be made.

2 On a sheet of paper, **construct** a diagram to describe the steps involved in mitosis. Label the parent cells and daughter cells.

3 **Identify** the name of the substance that provides instructions for the cell and where is it found.

4 **Explain** why a cell needs to copy its genetic material before dividing.

5 **Summarise** apoptosis and **identify** when it occurs.

Apply and analyse

6 **Identify** the two types of tumours and **describe** how they are different. Which type of tumour is also called 'cancerous'?

7 Red blood cells do not have a nucleus. **Explain** why this makes it impossible for them to undergo mitosis.

Skills builder: Conducting investigations

8 Consider the investigation that would be occurring to take the photo in Figure 4.

a **Identify** the risks and precautions the scientists would need to take when studying Tasmanian devils in the field.

b **Explain** why this investigation would only be carried out by professionals, and not by school students.

11.6 Different types of cells make up multicellular organisms

In this topic you will learn that:

- multicellular organisms require specialised cells to perform life's functions
- in complex multicellular organisms, there is a hierarchy of organisation: cells; tissues; organs; organ system; organism.

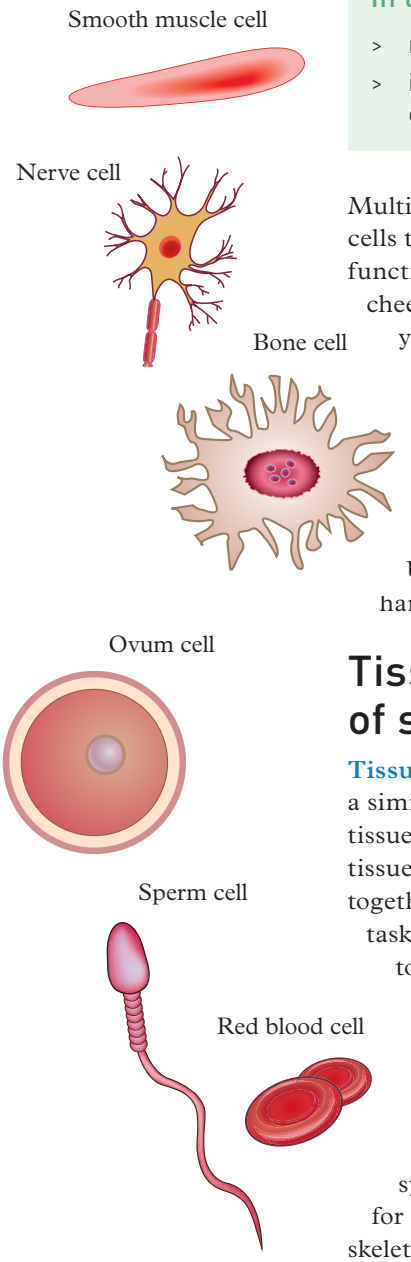


Figure 1 Cells in multicellular organisms are specialised for different functions.

Multicellular organisms have many different cells that are specialised to perform different functions. For example, the cells in your cheek are not the same as the cells in your liver, and hair cells are different from muscle cells. But all of these cells have a cell membrane, nucleus, mitochondria and other organelles that enable them to survive.

Cells in multicellular organisms rely on the entire organism to survive. Unicellular organisms, on the other hand, survive independently of other cells.

Tissues are groups of similar cells

Tissues are groups of cells that perform a similar task. For example, we have skin tissue, muscle tissue, nerve tissue, bone tissue and so on. Groups of tissues that work together form **organs**. Organs perform tasks that allow multicellular organisms to function. For example, your heart, brain, skin and intestines are examples of organs.

Organs form systems

The human body is made of major systems that perform specialised tasks for survival. These systems consist of the skeletal system, digestive system, respiratory system, excretory system, nervous system and circulatory system. The function of each of these systems can be seen in Table 1.

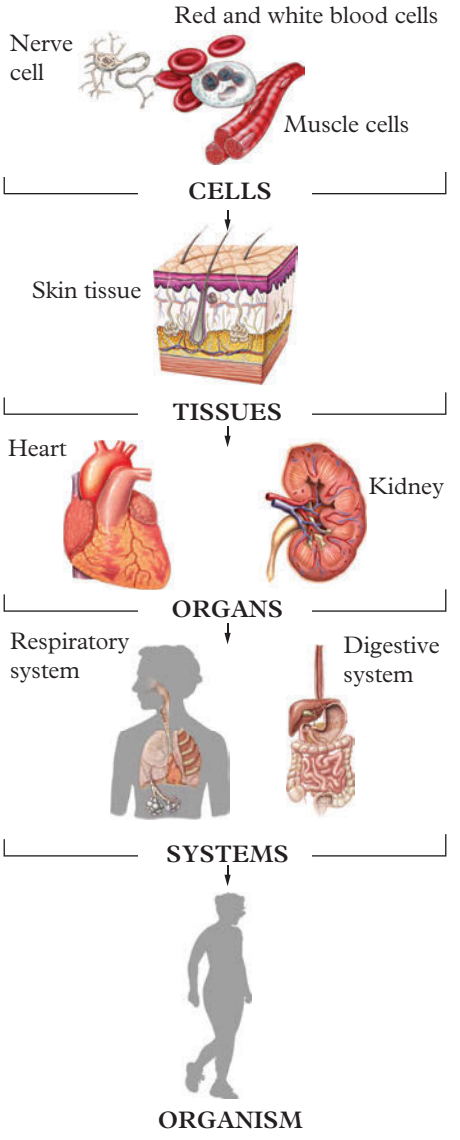


Figure 2 The formation of systems within the human body

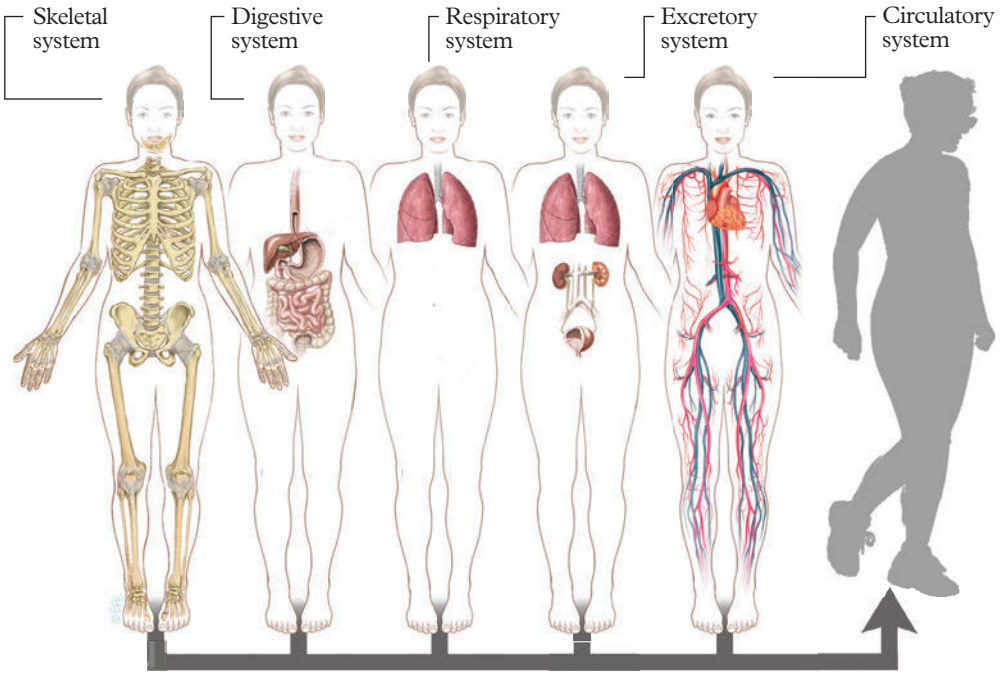


Figure 3 Human body systems work together to keep an organism alive.

organ
a group of different tissues that are self-contained and have a specific vital function

tissue
a group of the same cell type that performs a similar task

Table 1 Human body systems and their functions.

System	Organs and parts involved	What the system does
Circulatory	Heart, veins, arteries	Carries oxygen and nutrients to cells and waste materials away from cells via blood
Digestive	Mouth, stomach, small intestine, large intestine, rectum, anus	Breaks down food into substances small enough to be absorbed into the bloodstream; separates some waste
Excretory	Kidneys, bladder, urethra, skin, lungs	Kidneys filter out wastes and control the amount and content of body fluids; we sweat salts through our skin and exhale carbon dioxide from our lungs
Muscular	Muscles, ligaments, tendons	Attached to the skeleton; allows body to move
Nervous	Nerves, spinal cord, brain	Central nervous system (CNS) uses brain and spinal cord; electrical messages are sent to and from all parts of the body by the nerves
Respiratory	Lungs, windpipe, diaphragm	Takes in oxygen and transfers it to the blood so that it is taken to all other parts of the body; removes carbon dioxide from cells via blood
Skeletal	All bones, including spine, skull, pelvis, ribs	Gives body shape, holds it upright, supports and protects other organs; attached to muscles for movement

Check your learning 11.6

Recall and explain

1 Rank, in order of increasing complexity, the way cells are organised in our body.

2 **Identify** three examples of each of the following found in the human body:

- **a** cell type
- **b** tissues
- **c** organs
- **d** body systems.

3 **Explain** whether your tongue is a tissue, an organ or an organ system. **Justify** your answer.

Apply and analyse

4 **Explain** how two of the following organ systems rely on one another.

- the circulatory and respiratory systems
- the digestive and circulatory systems

Skills builder: Questioning and predicting

5 **Consider** Table 1, which outlines the different functions of the systems in the human body. Choose one of these systems and **identify** three questions about it that you could investigate using secondary sources. (THINK: What do you already know? What would you like to know more about?)

*REVIEW

Multiple choice

1 Which of the following is NOT found in an animal cell?
- **A** Mitochondria
- **B** A cell wall
- **C** Cytoplasm
- **D** A nucleus

2 What is the main role of respiration in a cell?
- **A** Convert light energy into glucose
- **B** Provide energy for the cell's activities
- **C** Provide oxygen for a cell's activities
- **D** Conduct cell division

3 The liver is an example of:
- **A** a cell
- **B** an organ
- **C** a body system
- **D** an organism.

Recall and explain

4 **Recall** two key ideas presented in the cell theory.

5 A cell membrane is 'partially permeable'. This means that only certain substances are able to cross the membrane. **Identify** some substances that would need to move through the membrane into the cell and others that would need to be removed.

6 Who was the first scientist to describe cells? **Recall** the cells that they drew.

7 **Describe** the benefit of using a stain when viewing some specimens.

8 **Recall** why a specimen needs to be really thin to be viewed under a light microscope.

9 **Define** the following terms.
- **a** Binary fission
- **b** Pathogen

10 **Explain** why unicellular organisms are always small, while larger organisms are always multicellular.

11 **Describe** the function of the following organisms.
- **a** Nucleus
- **b** Mitochondria
- **c** Chloroplast
- **d** Cell wall

12 **Recall** the function of cytoplasm.

13 Ribosomes are found in every cell on Earth. **Explain** the function that ribosomes perform in these cells and **identify** why it is so important.

14 **a** **Recall** the process used by cells to obtain energy.
- **b** **Describe** the process you identified in the previous question.

15 **Recall** the type of cell division used by bacteria.

16 **Explain** why programmed cell death (apoptosis) is necessary.

17 **Define** the following terms.
- **a** Mitosis
- **b** Cancer
- **c** Mutagen

18 **Identify** the systems that carry out the following functions.
- **a** Carries oxygen, nutrients and wastes around the body
- **b** Breaks down food and absorbs the nutrients into the body
- **c** Gives the body support, structure and protection

Apply and analyse

19 Light microscopes allow you to view living cells. Electron microscopes view either dead cells or cells that have been killed in the process of viewing them. **Identify** a situation or situations where an electron microscope may not be appropriate and **explain** why.

20 **Identify** the microscope most likely to have created the images in Figure 1.

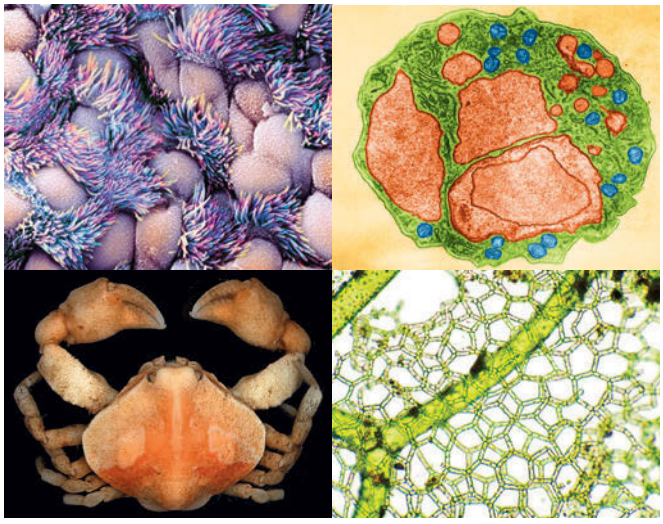


Figure 1 Images under microscope

21 Label the compound light microscope in Figure 2.

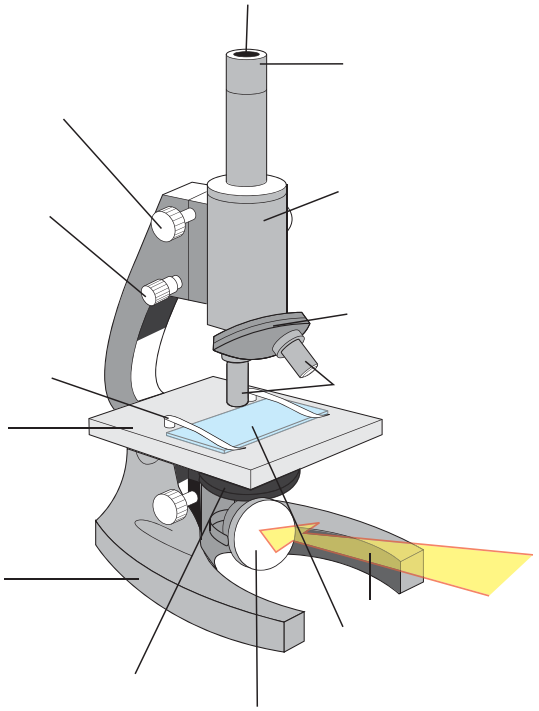


Figure 2 Compound light microscope

22 Animals cells have mitochondria, while plant cells have both mitochondria and chloroplasts. **Explain** this difference.

23 **Construct** a table that compares the organelles contained in an animal and a plant cell.

24 **Demonstrate** mitosis by constructing an appropriate flow chart.

25 **Distinguish** between protist cells and bacterial cells.

26 Figure 3 shows human nerve cells, white blood cells and a muscle cell. **Identify** each cell type, and **explain** how the shape and features of each cell enable it to perform a certain function within the human body.

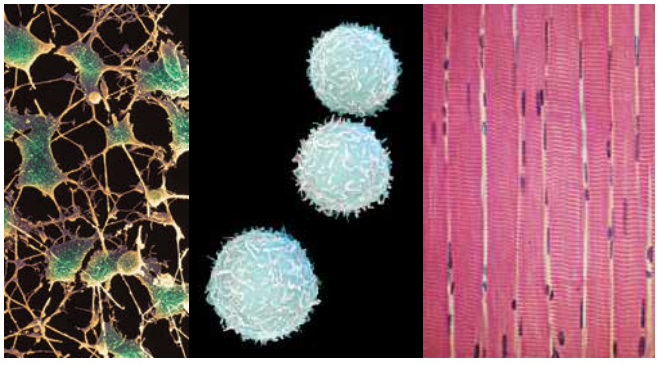


Figure 3 Different cells

Evaluate and create

27 **Discuss** how our understanding of cell structure and function has changed with the development of the microscope.

28 Two students prepare slides from different sections of a spring onion under a light microscope in their school laboratory. James views a section of the green, leafy part and observes many chloroplasts within each cell, but has difficulty identifying a nucleus in each cell. Emily views a section of the white stem part of the plant. She comments that a nucleus is clearly visible in most of the cells, but does not identify any chloroplasts.

- a **Propose** why James identified many chloroplasts within each cell when they appeared to be absent from the cells viewed by Emily.
- b Emily commented that she could identify a nucleus in most cells. If a nucleus is not visible in a particular cell, does this mean that the cell does not contain a nucleus? **Justify** your response.

Critical thinking

29 Similes are often used in creative writing to compare two things using the words 'like' or 'as'. **Explain** the similarities that allow these similes to be used.

- a Cells are like building blocks.
- b The nucleus is like a control centre.
- c The mitochondrion is like a power station.

30 **Predict** the number of mitochondria (low, medium or high) in the following cell types: heart muscle cell, skin cell, bone cell. **Justify** your decisions.

31 In multicellular systems, which system do you consider to be the most important? **Justify** your answer and **compare** your answer with that of your classmates.

Going further

32 Based on your knowledge of unicellular and multicellular organisms, why do you think all larger organisms, such as animals and plants, are multicellular? **Justify** your response.

33 **Investigate** the cell division process called meiosis. How is it different from the normal cell division process of mitosis? When does meiosis occur? **Construct** a table that summarises the similarities and differences between the two processes. Use a recognised method to acknowledge your sources of information.

Research

34 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

»Linking big concepts

In this chapter, big concepts about cells were discussed. Think of a creative way to represent these concepts and make links between them, using as many of the key words in the chapter as you can. You might use a concept map or mind map with each of the questions as major bubbles. You could choose to use diagrams only or draw a picture that shows all the aspects of the particles of life. The method of presentation that you select must enable you to share your ideas with others.

»Stem cells

Stem cells are cells in multicellular organisms that haven't become specialised yet – they're like blank canvases. Find out what scientists have learned about stem cells. Where do they find them? What can scientists use them for?

»DNA

DNA is sometimes called a recipe book for living organisms. But what is it? Find out more about what it does, what it looks like and who discovered it. Write out a fact sheet to share your findings with those of your classmates.



Figure 4 A digital illustration of a DNA helix

Reflect

Now that you've completed this chapter, reflect on your ability to do the following:

	I can do this.	I can't do this yet.
Identify that living things are made of cells.	☐	☐ Go to page 182.
Identify structures within cells, including the nucleus, cytoplasm, cell membrane, cell wall and chloroplast, and describe their functions.	☐	☐ Go to page 186–189.
Outline the role of respiration in providing energy for the activities of cells.	☐	☐ Go to page 188–189.
Identify that new cells are produced by cell division.	☐	☐ Go to page 194–195.
Distinguish between unicellular and multicellular organisms.	☐	☐ Go to page 190–193.
Identify that different types of cells make up the tissues, organs and organ systems of multicellular organisms.	☐	☐ Go to page 196–197.

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FUNCTIONING ORGANISMS

How do multicellular organisms survive and reproduce?

12

Have you ever wondered ...

- How do plants survive if they don't eat food?
- Which of your organs is the most important?
- What happens if your organs don't work correctly?



SCIENCE UNDERSTANDING

In this chapter you will learn how to:

- identify the materials required by multicellular organisms for the processes of respiration and photosynthesis
- explain that the systems in multicellular organisms work together to provide cell requirements, including gases, nutrients and water, and to remove cell wastes
- outline the role of cell divsion in growth, repair and reproduction in multicellular organisms
- describe the role of the flower, root, stem and leaf in maintaining flowering plants as functioning organisms
- describe the role of the digestive, circulatory, excretory, skeletal/muscular and respiratory systems in maintaining a human as a functioning multicellular organism
- outline the role of the reproductive system in humans.

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Check your Student obook assess for these digital resources and more:

QuizletLive
Compete in teams to test your knowledge.

Assess quiz
Before you start this chapter, assess your science skills.

Check your Teacher obook assess for these digital resources and more:

QuizletLive
Launch a quiz for your students on key concepts in this chapter.

12.1 Multicellular organisms need energy

In this topic you will learn that:

- autotrophs make their own food through photosynthesis
- photosynthesis requires water and carbon dioxide in the presence of sunlight and chlorophyll to produce glucose (sugar) and oxygen
- the majority of organisms convert glucose into useable energy in a process called cellular respiration.



Figure 1 The world's largest tree, the giant sequoia (*Sequoia giganteum*), is an autotroph.

Living things need food for energy to survive. Autotrophs make their own food (glucose) using light energy from the Sun in a process called photosynthesis. Heterotrophs, on the other hand, can't make their own glucose, so they get their energy by consuming other organisms. The majority of organisms convert glucose into important energy in a process called cellular respiration.

Photosynthesis

Photosynthesis is used by plants (and some other organisms) to transform light energy into chemical energy. Photosynthesis requires carbon dioxide, light energy and water. The light energy is obtained from the Sun.

Photosynthesis can be summarised by the following equation:

(Reactants) (Products)

Carbon dioxide + water → glucose + oxygen + water

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

Where does photosynthesis happen?

On average, a plant leaf has tens of thousands of cells and a single cell contains 40–50 chloroplasts. These chloroplasts contain the green pigment chlorophyll. It is this chlorophyll found in the leaf cells of a plant that captures the Sun's light energy and converts it into chemcial energy in the form of glucose.

The shape and arrangement of the leaves in many plants maximise their ability to absorb light energy and carry out photosynthesis.

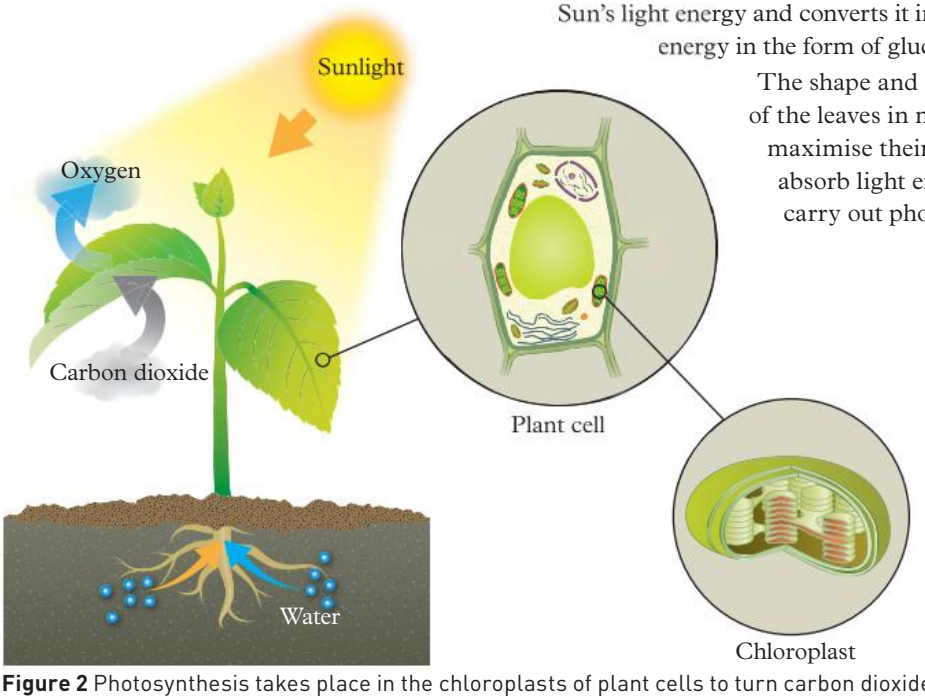


Figure 2 Photosynthesis takes place in the chloroplasts of plant cells to turn carbon dioxide and water into oxygen, glucose and water.

Cellular respiration

Cellular respiration occurs inside mitochondria. In this process, glucose and oxygen react to produce water, carbon dioxide and energy (**adenosine triphosphate**, or **ATP**). This energy is used by an organism to perform all life functions (remember: MR N GREWW). The general equation for cellular respiration is:

(Reactants) (Products)

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

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 6H_2O + 36ATP$$

Cellular respiration is similar to burning wood for fuel. Glucose is the molecule that our body uses for fuel. Each cell uses oxygen to break down glucose and convert the energy into ATP. Fats and proteins can also be converted into ATP in cellular respiration.

Oxygen is used during cellular respiration, and carbon dioxide and water are waste products.

Although cellular respiration is summarised as a single equation, it is actually a complex series of reactions. You can learn about this in Stage 6 Biology.

Body systems working together

Plants and animals have organ systems that help them to obtain the nutrients and gases they need for cellular respiration. These systems work together to keep the organism alive.

For example, we need our circulatory system to pump blood around our body. But that would be pointless if we did not also have our respiratory system providing oxygen to the blood. If one of our systems does not work, we run the risk of becoming sick and even dying.

adenosine triphosphate (ATP)
a compound that is used as the source of energy for cellular activities

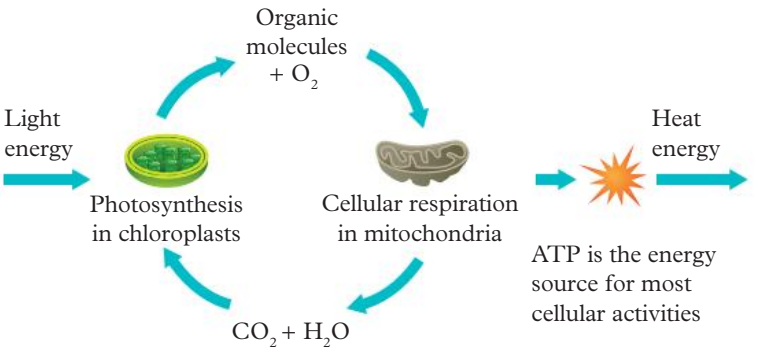


Figure 4 The structure of a photosynthesis–cellular respiration cycle

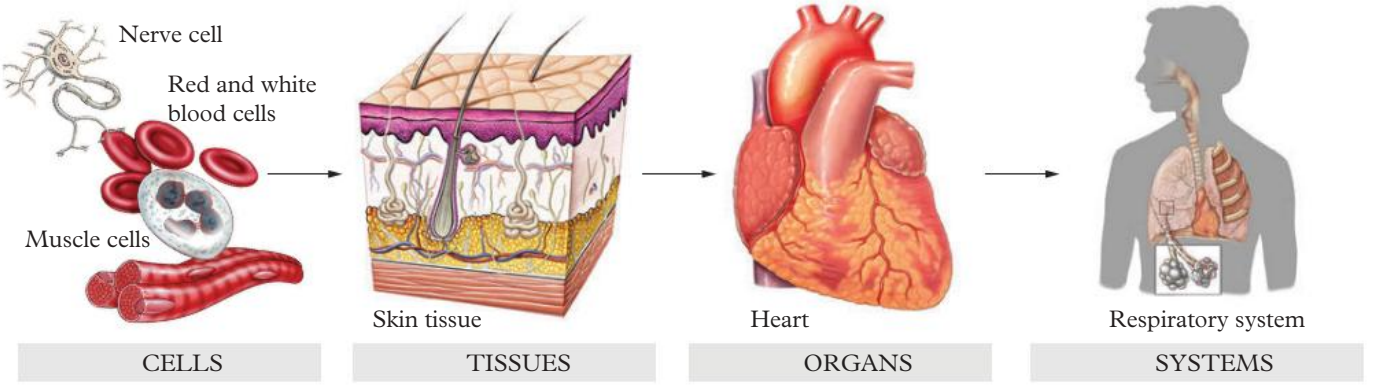


Figure 3 Body systems work together to provide the requirements for life.

Check your learning 12.1

Recall and explain

1 **Identify** what materials plant cells need to photosynthesise.
2 **Recall** the role of chlorophyll in photosynthesis.
3 **Identify** all the requirements cells need to conduct cellular respiration.
4 **Identify** the products and reactants of photosynthesis and cellular respiration.

Skills builder: Communicating

5 **Construct** a diagram to show the relationship between photosynthesis and cellular respiration. (THINK: What will you include to make sure people understand your diagram?)

12.2 Plants have organ systems to survive

In this topic you will learn that:

- plants have two organ systems: the root system and the shoot system
- plant organ systems interact to maintain the plant as a functioning organism.

stem
a plant organ involved in transporting sugars, water and nutrients

Although plants come in many shapes and sizes, there are two key organ systems common to plants: the root system and the shoot system. Roots absorb water from the soil. In the shoot system, stems transport water and nutrients around the plants, and leaves exchange gases and produce the glucose needed for energy.

Root system

Roots help anchor a plant to the soil and help it absorb water and nutrients. Most root cells have a series of small elongated hairs to increase the amount of surface area that can take in water.

osmosis
the movement of water through a selective membrane from an area of low 'salt' concentration to an area of high 'salt' concentration; occurs in root cells

vascular bundle
groups of tubes found in plant stems that carry water and nutrients around the plant

xylem
the tissue in plants that carry water from the roots to the rest of the plant

First the roots take mineral salts from the soil and store them in their cells. This makes the inside of the roots more 'salty' than the soil. Water molecules are attracted to the mineral salts in the root cells. As a result, water moves through the root cell membrane and into the plant. This process is called **osmosis**. During osmosis, water molecules move across a semipermeable membrane (in this case, the cell walls of the cell membrane of the root), from an area of high water (low salt) concentration (outside of the plant) to an area of low water (high salt) concentration (inside the plant).

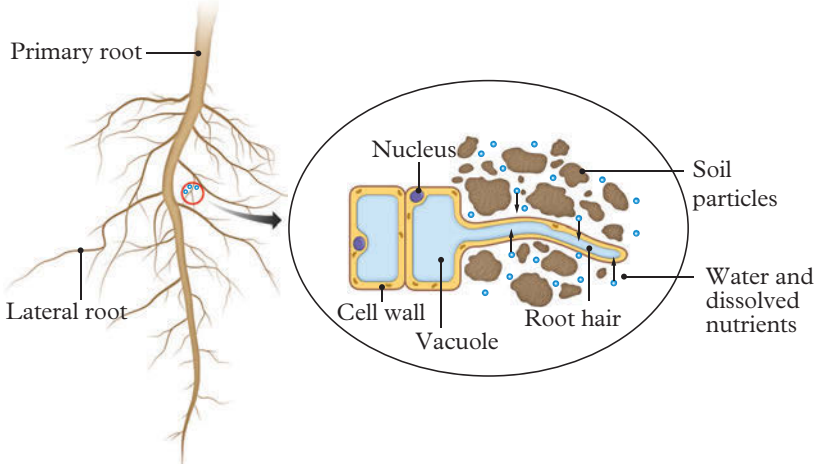


Figure 1 Root hairs increase the surface area over which osmosis can occur.

Shoot system

The shoot system is made up of the **stem** and leaves of a plant. The shoot system can generally be found above the ground, while the root system is usually found below.

Plant stem

The stem of a plant is the organ responsible for maintaining

- the upright structure of the plant
- the transport of water and dissolved nutrients from the roots to the leaves
- the subsequent transport of glucose produced during photosynthesis in the leaves to all other parts of the plant. The stem of the plant contains vascular bundles. There are two main structures in a **vascular bundle**: xylem and phloem.

The **xylem** (pronounced 'xi-lem') is a straw-like structure that moves the water from the roots to the leaves of the plant. Water molecules like to stick together – you can see this in the way a drop of water forms a spherical shape. When water evaporates from the leaves

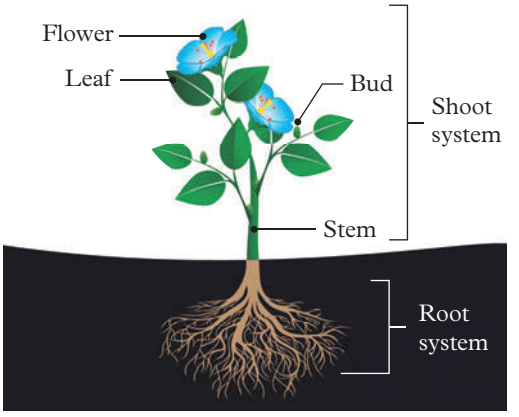


Figure 2 The organ systems and main structures of a flowering plant

CHALLENGE 12.2A: Locating the stomata of a leaf Go to page 383.

CHALLENGE 12.2B: Locating the xylem and phloem in a stem Go to page 384.

CHALLENGE 12.2C: Modelling root cells Go to page 384.

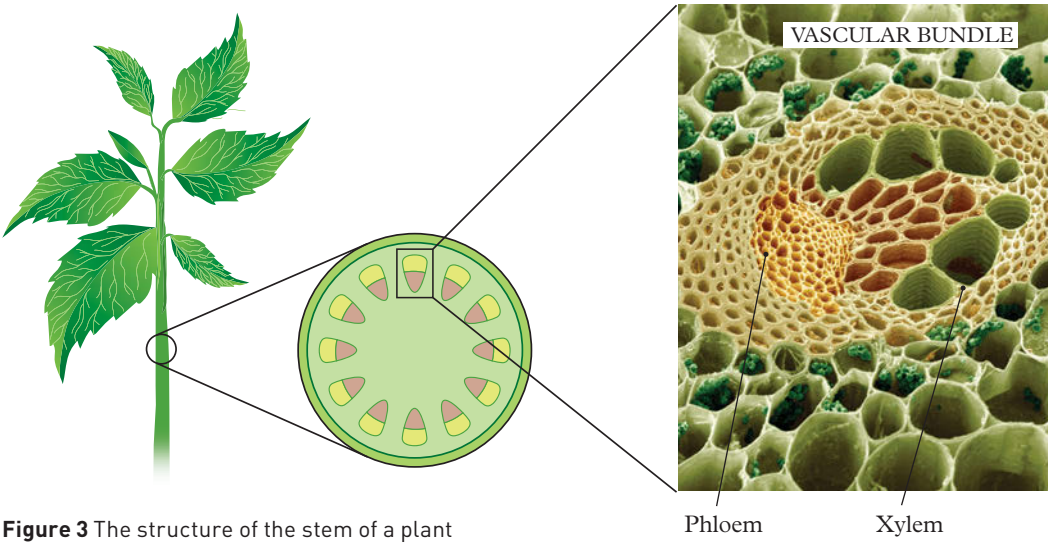


Figure 3 The structure of the stem of a plant

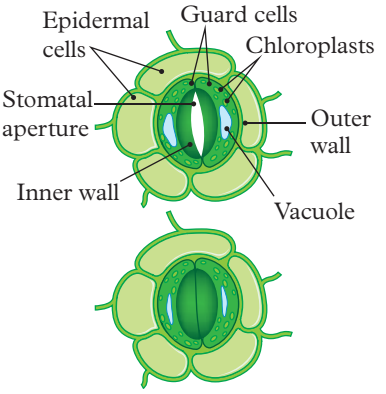


Figure 4 The opening and closing of plant stoma to control gas exchange and water loss

at the top of a plant (transpiration), other water molecules move up to replace it. This can pull water molecules from the roots to the top of a 10 metre tree.

The **phloem** (pronounced 'flo-em') is another network of cells in the plant stem that transports the glucose produced in the leaves to other parts of the plant. These sugars are needed for all cells in the plant to produce the energy they need to stay alive and perform their function.

Leaves

The leaves of a plant are involved in gas exchange and water regulation. The carbon dioxide needed for photosynthesis enters via the leaf stomata, and the excess oxygen produced exits via the stomata.

Plants obtain carbon dioxide and release oxygen through microscopic pores called stomata (singular 'stoma') found in the leaves. Guard cells regulate the exchange of gases and water loss by controlling the opening and closing of the stomata (see Figure 4).

Each stoma has two specialised guard cells controlling the opening and closing of the pore. By taking on more water, the guard cells swell, resulting in an increased opening of the stoma. By releasing water, the guard cells shrink and the stoma closes. This process regulates both gas exchange and water loss from the plant. The regulation of water loss is essential in ensuring the plant does not dehydrate and assists in cooling the plant leaves in hot weather.

phloem
the vascular tissue found in plant stems that carry the sugars around the plant

Check your learning 12.2

Recall and explain

1 **Identify** three organs found in most plants and **describe** their function.
2 **Explain** the role of root hairs.
3 **Recall** the definition for 'osmosis'.

Apply and analyse

4 **Compare** the function of xylem and phloem.
5 Some florists sell blue orchids, which are artificially coloured. Use your knowledge of plant systems to **predict** how these orchids may have become blue.

Evaluate and create

6 **Assess** how the root and shoot systems would help a plant to conduct photosynthesis and cellular respiration.

Skill builder: Planning investigations

7 Amy was asked to investigate the rate that tomato plants grow when they receive different amounts of water. She set up three pots and planted a tomato plant in each of them. Each day for a month, she watered pot 1 with 20 millilitres of water, pot 2 with 500 millilitres of water and pot 3 with 1 litre of water.
   a **Identify** the independent and dependent variables in this investigation. (THINK: What factor is being changed, and what is being measured?)
   b **Identify** an additional two variables that might need to be controlled in this investigation. (THINK: What might influence the results?)

12.3 Flowers are for sexual reproduction

In this topic you will learn that:

- flowers are the reproductive organ of flowering plants
- plant sexual reproduction produces seeds.

gamete
a sex cell; in humans it is the egg and sperm

ovum
female gamete of flowering plants

stigma
the part of the female reproductive structure in flowering plants; the tip of the carpel where pollen is deposited

ovary
the enlarged basal portion of the carpel that contains the ovum

stamen
male reproductive structures in a flowering plant

pollen
male gamete of a flowering plant

pollination
the transfer of pollen (male gamete) to a stigma (female structure)

self-pollination
the pollination of a flower by pollen from the same flower or from another flower on the same plant

The purpose of a flower is not necessarily to be sweet smelling and beautiful: it is to contain the sexual reproductive organs of the plant and to help fertilisation to occur.

Pollination

A gamete is an organism's reproductive cell. The female **gamete**, also called an **ovum**, is located at the base of the **stigma** inside the **ovary**. The stigma and ovary are connected via the style. Combined, these female parts are called the carpel. The male reproductive structure is referred to as the **stamen**. The stamen consists of the **pollen**-containing anther situated at the end of a long filament.

For fertilisation to occur, the male gamete (pollen) needs to find its way from the anther to the ovum. This requires **pollination** – the process of pollen attaching to the stigma and 'digging' a pollen tube down to the ovary.

Flowers are a diverse bunch. Some smell pleasant, while others replicate the smell of decaying flesh. Why the diversity? Flowers usually need assistance from other organisms (insects, birds or mammals) or the environment (wind or rain) for pollination to occur. Flowers have evolved to attract pollinators specific to the plant.

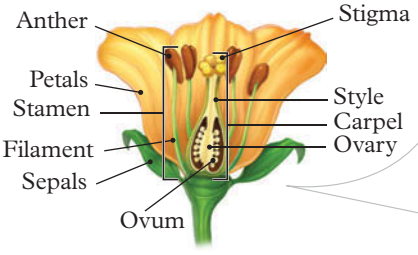


Figure 1 Basic structure of a flower

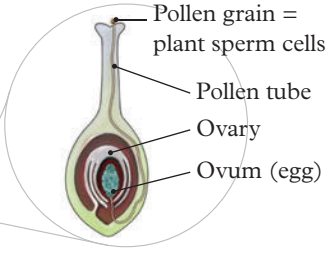


Figure 2 Structure of the carpel, with key structures labelled

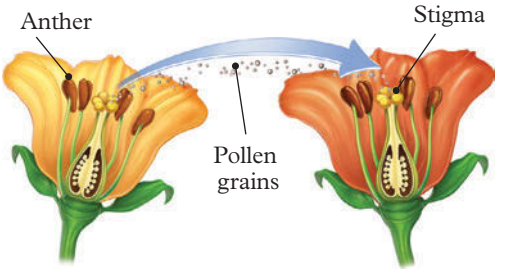


Figure 3 Cross-pollination

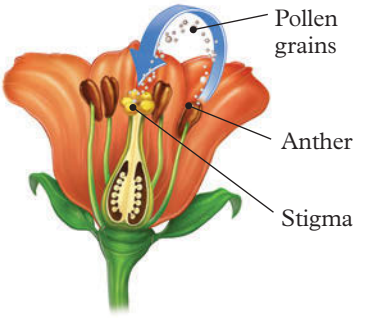


Figure 4 Self-pollination

Self-pollination involves pollen from a flower landing on its own stigma or that of another flower on the same plant. **Cross-pollination** occurs when pollen from a flower lands on the stigma of a flower on a different plant, combining two different sets of genetic material. Just like animals, the pollen from one flower can only fertilise flowers from the same or similar species.

When a male and female gamete combine, it becomes a zygote. After fertilisation, the ovary swells to become a fruit, which provides nutrition and protection for the **zygotes** to grow inside the seeds.

INVESTIGATION **12.3:** Flower dissection
Go to page **386**.

Not all flowers are the same

If a flower smells, it is usually to attract a pollinator – but not all smells are sweet. Rafflesia is a flower native to Borneo that smells like rotting flesh to attract flies for pollination (see Figure 5).

The colour of a flower is also important for attracting pollinators. Birds tend to pollinate red flowers, whereas insects may be more attracted to a wide range of colours. Mammals that feed at night will rely on strong scents and not on colour at all.

Some flowers have modified structures to suit their pollinators. Birds may damage flowers with their sharp beaks when they drink the nectar, so flowers need to be strong. Insects can be small and need to be forced to brush against pollen, followed by the stigma, so the flower may be full of obstacles or simply a tight fit (see Figure 6).



Figure 6 Rainbow lorikeet on a Banksia

Sexual spores

If you've ever had a good look at a fern, you will have noticed brown patches on the underside of fern fronds. These brown patches are specialised cells that make and release spores onto the ground. The spores are tiny reproductive structures that have half the genetic material of seeds. They grow into tiny heart-shaped plants called prothalli, which are made up of male and female reproductive organs. Male and female gametes are produced and released when it rains to hopefully find a match for fertilisation. The little plant then dies, but the fertilised eggs grow into new ferns.

Vegetative reproduction

Some plants reproduce asexually, meaning they can reproduce without gametes or pollination. This is called **vegetative reproduction**, which can occur in the specialised cells and tissues of roots, stems and leaves of some plants. Vegetative reproduction often involves part of the plant breaking off and surviving as a new organism that is genetically the same as the original 'parent' plant. For example, if you take a cutting from a plant, you can plant it elsewhere and it will continue to grow.

vegetative reproduction asexual reproduction in plants where identical offspring are grown form the tissue of a parent plant

cross-pollination the exchange of pollen and ova between different plants of the same species

zygote the first cell of a new organism after fertilisation



Figure 5 Rafflesia



Figure 7 Fern 'sori' produce spores for reproduction.

Video
Pollination and fertilisation

Check your learning 12.3

Recall and explain

1 **Recall** the name of the structure that holds a plant's sexual reproductive systems.
2 **Describe** a spore.

Apply and analyse

3 **Compare** fertilisation and pollination.
4 **Contrast** self-pollination and cross-pollination.
5 Mint is common in herb gardens; it reproduces with little flowers and uses vegetative reproduction. **Explain** why it would it be difficult to get rid of mint once it has spread through a garden bed.

Evaluate and create

6 **Investigate** why the leaves on some trees turn red, yellow or orange in winter. How does this help the plant to survive?

Skills builder: Conducting investigations

7 **Examine** Investigation 12.3 'Flower dissection' (page 386).
a **Identify** three risks involved in this investigation. (THINK: What could be dangerous?)
b **Identify** how you will conduct the investigation safely. (THINK: What could you do to avoid the risks?)

12.4 The digestive system breaks down food

In this topic you will learn that:

- the digestive system is responsible for the breakdown of food and the absorption of nutrients
- organs of the digestive system include the mouth, stomach, small intestine and large intestine.

digestion
the process by which food is broken down and absorbed into the blood for transport to the cells

Humans have many organ systems. Each of these systems works together to ensure we have all the requirements for life. **Digestion** is the process by which food is broken down and absorbed into your blood for transport to your cells. The food we eat provides us with the energy to stay alive, the building materials for growth and repair, and fibre to help move it all through. Nutrients are soluble substances that are absorbed by the blood and circulated around the body to where they are needed.

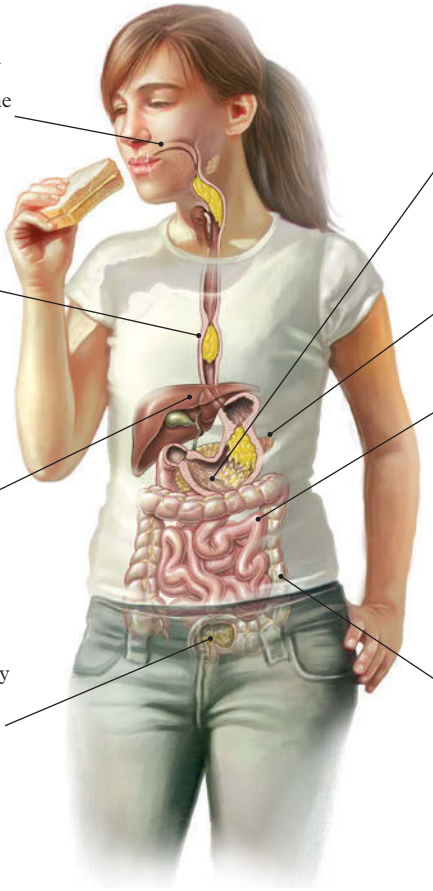
Your digestive tract is made up of a group of organs in the digestive system that form a tube travelling from your mouth to your anus. Along the way, food is broken down and absorbed across the intestinal walls into the blood. The internal walls of the intestines are wrinkly to increase their surface area for absorption into the blood. Food that is not required by the body remains in the digestive tract until the end, where it is excreted. Figure 1 shows what happens as food moves down through the digestive tract.

Teeth and mouth
The teeth are responsible for the physical breakdown of food and the tongue is important in pushing the food towards the teeth. Salivary glands make saliva, which contains enzymes to start chemical digestion.

Oesophagus
The oesophagus is a tubular muscle that forces food down to your stomach in a process called peristalsis.

Liver and gall bladder
The liver makes a mixture of chemicals called bile, which is used to digest fat and neutralise (deactivate) stomach acid. The bile is stored in the gall bladder until food reaches the small intestine. Bile is then released into the small intestine through a tube called the bile duct. Food does not travel through the liver.

Rectum and anus
The rectum is the final part of the journey for what is now solid, undigested food, or faeces. The rectum stores faeces until it starts to become full. As the rectum starts to stretch, messages are sent to the brain to make you realise that you need to go to the toilet. Rectal muscles push the faeces out of the ring of muscle at the end of the rectum called the anus.



Stomach
The stomach stores food for about 3 hours while it uses gastric juice (stomach acid) to help digest the food. The food in your stomach looks nothing like what you ate for dinner. It is very runny, warm and smelly and has a totally different taste. This mixture is called chyme.

Pancreas
The pancreas makes pancreatic juice, which contains a mixture of digestive enzymes and also neutralises stomach acid. Food does not travel through the pancreas.

Small intestine
The small intestine is called 'small' because it is quite narrow. If you laid a small intestine out in a straight line, it would be approximately 5 m long. The intestines are really important because they absorb the nutrients that all the cells of the body require. The ability to absorb nutrients is increased by projections, called villi, along the inner wall of the intestine that increase the surface area for absorption. Bacteria in the small intestine also help with digestion. Chyme takes about 5 or 6 hours to pass through the small intestine.

Large intestine
The large intestine is also called the colon and is wider but shorter than the small intestine. The large intestine is approximately 1.5 m long. By the time the chyme reaches the large intestine, most nutrients have been absorbed into the bloodstream. However, some vitamins are absorbed from the large intestine. Water is also absorbed into the bloodstream from the large intestine. Chyme stays in the large intestine for up to 14 hours, or sometimes longer.

Figure 1 The structure of the digestive system, with key structures and functions labelled

INVESTIGATION **12.4A:** Digesting protein
Go to page 387.

INVESTIGATION **12.4B:** What if an enzyme was boiled?
Go to your obook.

Physical and chemical digestion

Your teeth are responsible for the physical breakdown of your food – that is, physical digestion. This involves the manual breaking up of food into smaller pieces. There are three main types of teeth in your mouth that perform this process. The front teeth called incisors, the pointy teeth next to the incisors called canines and the rest of your teeth, which are flatter and called molars. You also have your tongue, a large muscular organ, that can push upwards, sideways and backwards. When you swallow your food, the muscles behind the food squeeze tight and the muscles in front of the food relax. This forces the food to move in a process called **peristalsis**.

The saliva in your mouth contains different types of **enzymes**. Enzymes are chemicals that speed up reactions. In the digestive system, enzymes assist in breaking up smaller pieces of food into nutrients that are small enough to be absorbed by the body – this is **chemical digestion**. For example, saliva contains an enzyme called amylase that breaks up carbohydrates, such as starch in bread and biscuits.

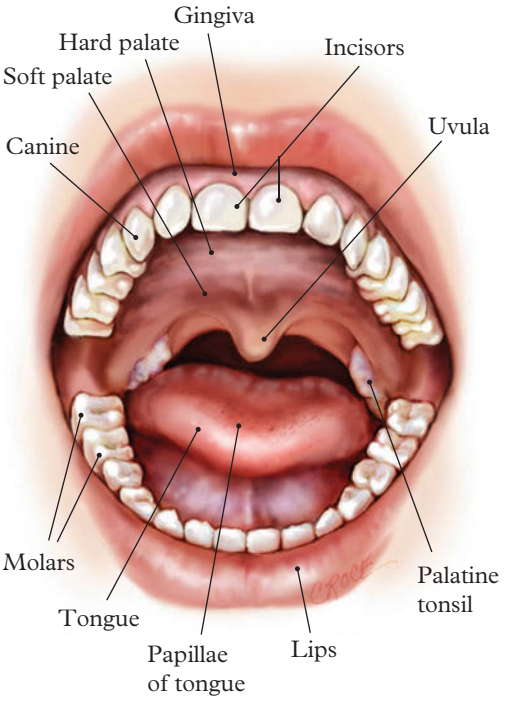


Figure 2 The teeth and mouth physically break down food.

Video
Digestion and enzymes

peristalsis
when muscles behind the food squeeze tight and the muscles in front of the food relax, causing the food to move along the throat or intestines

enzymes
a group of proteins that help to speed up chemical reactions

chemical digestion
the chemical breakdown of food into simpler substances that can be absorbed into the blood

Check your learning 12.4

Recall and explain

1 **Identify**, in order, the organs of the digestive system that food moves through, from the mouth to the anus.
2 **Explain** how saliva would make it easier to eat dry biscuits.
3 **Recall** which organs are involved in digestion but do not have food pass through them.
4 What are villi? What is their function?

Apply and analyse

5 **Describe** and then **contrast** physical and chemical digestion. Which occurs in the stomach?
6 **Explain** how the digestive system of a rabbit would vary in comparison to a fox.

Evaluate and create

7 **Investigate** the digestive system of an animal of your choice. How is your chosen digestive system similar to, and different from, the digestive system of humans? How does the structure of your animal's digestive system relate to the food it eats?

Skills builder: Planning investigations

8 Charlotte and Henry were planning an investigation, which involved members of their class eating different types of biscuits. **Explain** why this might be an unsafe activity for some of the students in their class. (THINK: How might food be dangerous?)

12.5 The circulatory system carries substances around the body

In this topic you will learn that:

- the circulatory system is responsible for transporting substances around the body
- organs of the circulatory system include the blood, heart and blood vessels.

The circulatory system is the body's transport system and is responsible for moving blood around your body.

Blood

blood
the liquid that circulates in the blood vessels and contains a combination of cells, cell fragments, liquid and dissolved substances

Blood is a combination of cells, cell fragments, liquid and dissolved substances. Each of its components has a different function.

- Red blood cells carry oxygen on a molecule called haemoglobin. The oxygen is picked up in the lungs and transported to all other cells of the body. The waste carbon dioxide, is then carried in the blood back to the lungs for removal.
- White blood cells are required for the immune system. They play a role for example in fighting foreign disease-causing pathogens such as bacteria and viruses.
- Plasma is a yellowish liquid made up mainly of water and dissolved substances. It makes up more than 50% of the blood volume. Nutrients absorbed into the blood from the digestive system are dissolved in the plasma for transport around the body.
- Platelets are cell fragments that move to areas where you have an open wound to form a blood clot.

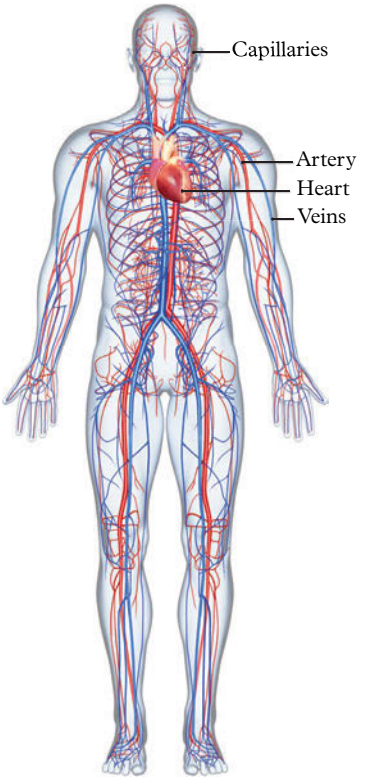


Figure 1 The structure of the circulatory system, with key parts labelled

The heart

The heart is a large muscle about the size of your fist that acts like a pump. It is made of four chambers: two atria (singular 'atrium') at the top and two ventricles at the bottom. The ventricle on the right side of the heart pumps blood to the lungs to 'drop off' carbon dioxide and 'pick up' oxygen. This oxygenated blood moves back to the left atrium and on to the left ventricle. The more muscular left ventricle pumps blood out of the aorta from the top of the heart and around the body. Valves keep the blood moving in the right direction until it gets back to the right atrium of the heart.

Blood vessels

blood vessel
a tube in the body that carries blood

Blood travels through tubes called **blood vessels** (see Figure 3). Just like our roads, blood vessels have different sizes and structures depending on the amount of blood they need to carry, as well as the speed of the blood and whether it is picking up or dropping off substances.

INVESTIGATION **12.5:** Heart dissection
Go to page **388**.

CHALLENGE **12.5:** Modelling blood flow
Go to page **389**.

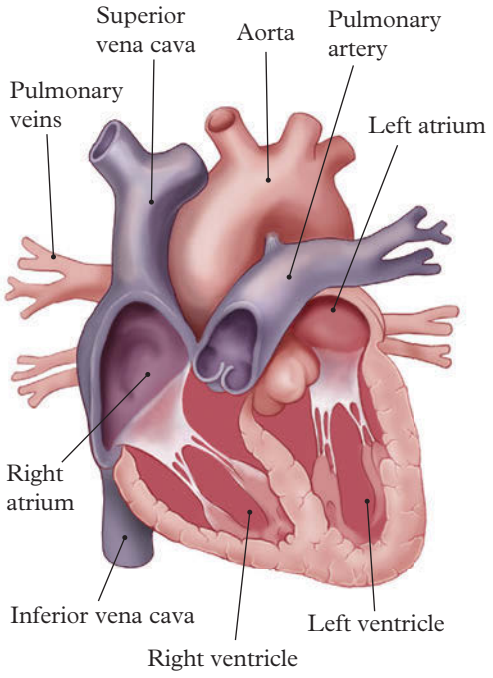


Figure 2 This diagram shows the heart, as well as some of the major blood vessels that travel to and from the heart. The diagram uses a common convention that shows the arteries in red and the veins in blue.

Arteries are the largest blood vessels (see Figure 4). They have thick, muscular walls to cope with high pressure and to help move the blood along. Arteries carry blood away from the heart. The blood is at a higher pressure in the arteries because it has just been pumped by the heart. Arteries branch into arterioles (smaller arteries).

Capillaries are the thinnest of the blood vessels: their walls are only one-cell thick to allow substances, such as oxygen, carbon dioxide and nutrients, to pass easily in and out of the blood. Capillaries are the vessels connecting the arteries and veins.

Veins always carry blood back to the heart to be pumped elsewhere. Veins are similar in size to arteries, but they only have a small amount of muscle in their walls. To avoid any blood going backwards due to a lack of pressure, veins have one-way valves in them.

vein
a thin blood vessel that carries blood back to the heart

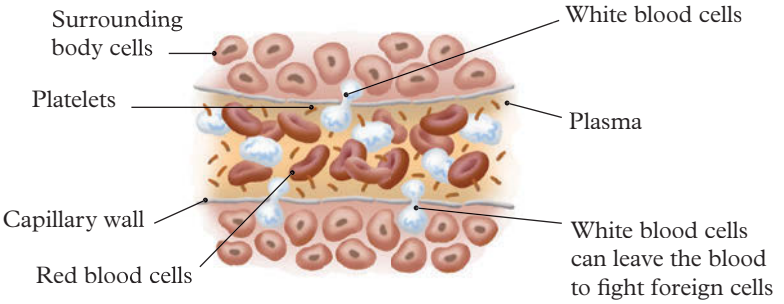


Figure 3 A cross-section of a blood vessel

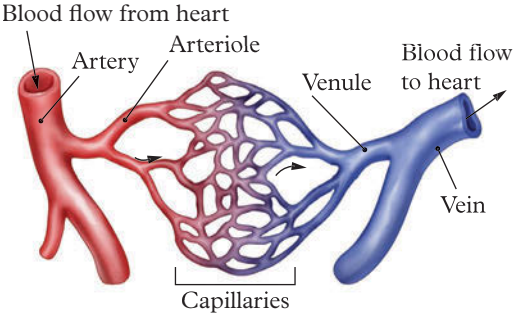


Figure 4 Capillary bed, showing the relationship between arteries, veins and capillaries

artery
the thick muscular-walled blood vessel that carries blood away from the heart under pressure

capillary
a blood vessel with a wall only one-cell thick, allowing for substances to easily pass into and out of the blood

Check your learning 12.5

Recall and explain

1 **Recall** how many chambers there are in the heart.

2 a **Describe** the path of blood through the chambers of the heart. Include the names of the veins and arteries involved. Refer to Figure 2 to help you.

b Complete the following flow chart to show the path of blood through the chambers of the heart.

Body → _____ → _____ → lungs → _____ → _____ body

Apply and analyse

3 **Explain** why the heart needs to pump faster during exercise.

4 If a person is dehydrated, their blood becomes thicker. **Explain** the effect this could have on the heart.

Evaluate and create

5 **Construct** a table or diagram to communicate the differences between the structure and function of arteries, veins and capillaries.

Skills builder: Questioning and predicting

6 **Examine** Figure 3, a cross-section of a blood vessel.

a Write down three observations about Figure 3.

b Write one scientific question based on one of your observations. (THINK: Make sure your question is specific.)

12.6 The excretory system removes wastes

In this topic you will learn that:

- the excretory system is responsible for the removal of waste products from the body
- organs of the excretory system include the kidneys, skin, liver and lungs.

urea
a form of nitrogen waste product formed by the body

excretion
the process of removing wastes from bodies

nephron
a tiny structure in the kidneys that filters the blood

The human body, like all organisms, relies on a careful balance of inputs and outputs to work properly. Our body systems create products, as well as wastes that need to be removed, for the body to continue functioning. The process of removing wastes is called **excretion**.

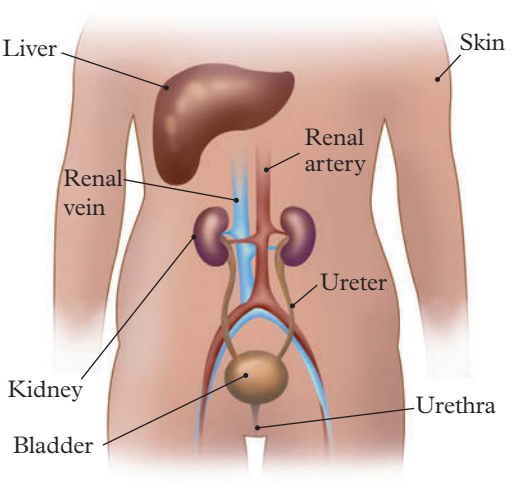


Figure 1 The structure of the excretory system, with key parts labelled



Figure 2 The salt that you eat helps substances move in and out of cells. However, if there is too much salt in your body, things get out of balance. Your body gets rid of the excess salt by filtering it out through the kidneys.

Waste

Wastes are the unwanted or unusable substances produced by our bodies. These waste products need to be removed from our bodies to avoid damage (see Figure 1). Water is important in controlling wastes because it can dilute harmful substances, diluting their impact at the same time.

When your body digests proteins, it breaks them down into smaller molecules called amino acids. However, the body cannot store the amino acids that it doesn't use immediately. Your liver breaks down these excess amino acids into other substances for energy. When the liver does this, it produces a very toxic substance called ammonia. The liver then uses energy to change the ammonia into a safer substance called **urea**, which is also filtered by the kidneys for removal.

The kidneys

You have two kidneys, one on each side of your lower back. They are approximately 10–12 centimetres long. Blood carrying waste products enters your kidneys to be filtered by tiny structures in the kidney called **nephrons**. At the end of this filtering process there are two main outputs: clean blood and urine.

The kidneys also regulate the amount of water and salt that are in your blood. For example, if you do not drink enough water, you might notice that you produce less urine, which is more concentrated and yellow.

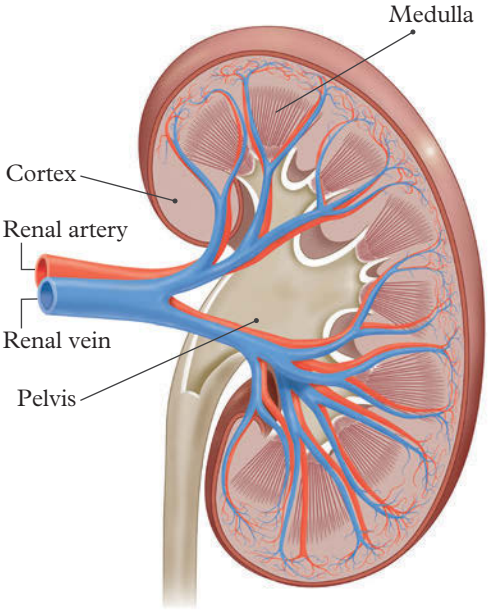


Figure 4 The basic structure of the kidneys, with key parts labelled

The skin

The skin is the body's largest and most sensitive organ, accounting for about 16% of our body weight – approximately 11 kilograms in the average person. Human skin consists of three layers: epidermis, dermis and subcutaneous fat layer.

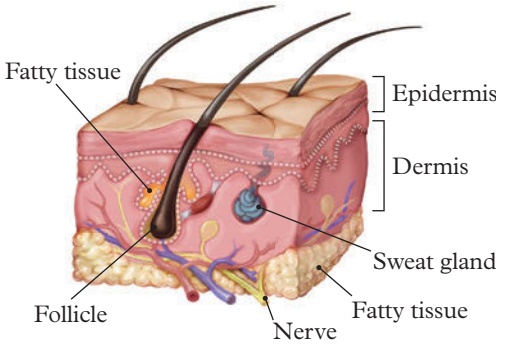


Figure 5 The structure of skin, with key parts labelled

The skin plays a very important role in regulating body temperature and cooling the body through evaporation of sweat. If you've ever licked your upper lip after exercise, you will know that your sweat is very salty. Sweat also contains waste products such as salts and urea.

The skin also has many other functions, including providing protection and sensing changes in the environment.

The liver

All of our food has to be metabolised, or processed. **Metabolism** is the name given to the chemical reactions that occur in the body. These reactions can break down substances or build new substances. The liver is responsible for the metabolism of many substances, especially waste substances. Dangerous substances are often changed into less dangerous forms by the liver before their removal from the body.

metabolism
chemical reactions that occur in the body

The liver is also responsible for the excretion of bile. The bile assists in the removal of waste products after they have been metabolised in the liver, and the breakdown of fats in the small intestine during digestion.

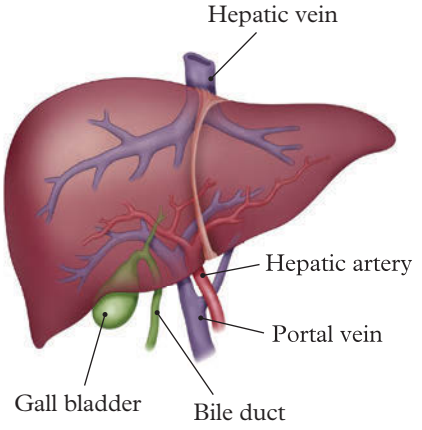


Figure 6 The structure of the liver, with key parts labelled

Check your learning 12.6

Recall and explain

1 **Explain** the word 'excretion'.
2 **Identify** two organs involved in excretion.
3 **Describe** how your body can get rid of the following wastes.
   a Salt
   b Water
   c Urea

Apply and analyse

4 If someone passes blood in their urine, it is a likely sign of kidney damage. **Propose** a reason why.
5 **Identify** an example of where the excretory system interacts with another body system to maintain the health of humans as a functioning organism.

Evaluate and create

6 **Investigate** a disease of your choice associated with an organ of the excretory system. Design a health brochure that contains:
   - a labelled image of the organ
   - details on the normal function of the organ
   - details of the disease and how it affects normal function
   - information to assist people with the disease and help manage symptoms.

Skills builder: Questioning and predicting

7 A scientist was conducting a study on the impact of exercise on the concentration of urine. He tested a group of marathon runners and a group of people who did not exercise.

Predict what effect running a marathon would have on the quantity and concentration of urine. (THINK: What do you know about how the kidney works?)

12.7 The skeletal and muscular systems support movement

*

In this topic you will learn that:

- the skeletal and muscular systems support movement, give the body structure and protect internal organs

cartilage
firm, flexible connective tissue that reduces the friction between joint bones

ligament
a type of connective tissue that connects bones to other bones

tissue
a group of cells that do a similar task

The skeletal and muscular systems work together so that we can move. The ability to move is essential for living things to survive. It means we can find and eat food or run away from danger. The skeletal and muscular systems also provide our bodies with the structural support we need to stand upright and they also act as a hard protective shield for our internal organs.

The skeletal system

The skeletal system is made up of bones, joints and **cartilage** and provides a framework for the muscles.

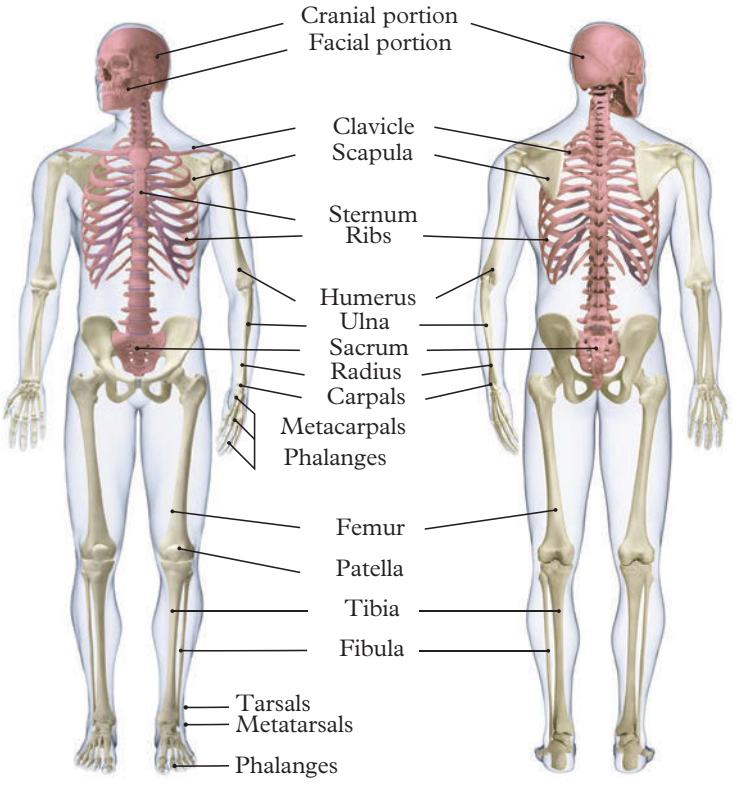


Figure 1 The main bones of the skeletal system

Bones

There are 206 bones of different shapes and sizes in an adult human. The main bones of the skeletal system are shown in Figure 1.

Bones are made up of living tissues that can repair themselves when they are damaged or broken. The outside of the bone is made up of hard, compact bone. Inside the compact bone is spongy, cancellous bone. This spongy bone is filled with bone marrow – the site of blood cell production.

Joints

A joint is where two bones connect together. Joints are held together by **ligaments**, a type of connective **tissue**. Different types of freely moving joints are:

- hinge joints, such as the elbow or knee, which act like hinges on a door in one direction
- ball-and-socket joints, such as the shoulder or hip, which allow movements in many directions
- pivot joints, such as the vertebrae in the neck, which fit one rounded bone into another to allow for rotating movement.

Many bones are protected at the joint by another type of tissue called cartilage. This cartilage reduces the friction between bones as they rub together.

The muscular system

Muscles allow us to raise our eyebrows, smile, kick a ball or carry a bag. Without them, our bones would not be able to move. Organs, such as the heart, are also made up of muscle tissue.

There are three types of muscle in the muscular system:

- Skeletal muscles are attached to our bones for movement.

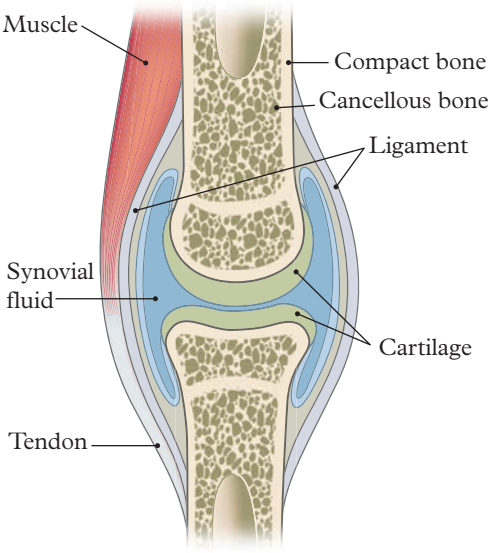


Figure 2 A typical joint

- Cardiac muscles move involuntarily, automatically contracting to coordinate our heartbeat.
- Smooth muscles also move involuntarily to move our other internal organs, such as the intestines.

Skeletal muscles work in pairs by contracting and relaxing. When one muscle contracts, the other muscle in the pair relaxes. When we bend our elbow, the bicep muscle (between our elbow and shoulder) contracts, which shortens the muscle. Meanwhile the opposite tricep muscle relaxes and lengthens.

Skeletal muscles are connected to the bone by **tendons**. Cardiac and smooth muscles, on the other hand, are not connected to the bone.

tendon
a type of connective tissue that connects muscle to bone

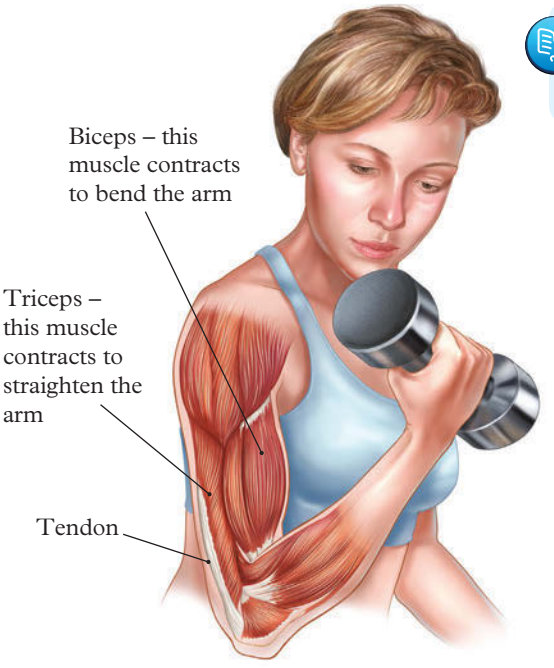


Figure 3 Skeletal muscles move the body in pairs by contracting and relaxing.

Resource
STEM activity: Bone density

Check your learning 12.7

Recall and explain

1. **Identify** two functions of the skeletal system.
2. **Describe** how bones, joints, cartilage and ligaments function together.
3. **Identify** the three types of muscle cells.

Apply and analyse

4. **Contrast** tendons and ligaments.
5. **Propose** a reason why skeletal muscles occur in pairs but smooth muscles do not.

Evaluate and create

6. **Discuss** how the skeletal and muscular systems help to keep an organism alive.

Skills builder: Processing and analysing data

7. In 2018, a report released by Osteoporosis Australia summarised the average number of bone fractures per day in each state. **Interpret** the graph in Figure 4. (THINK: What information can you find in the title and axis labels?)
   - a. Which state has the most fractures per day?
   - b. Which state has the fewest fractures per day?
   - c. **Suggest** a reason why New South Wales may record more bone fractures than other states.

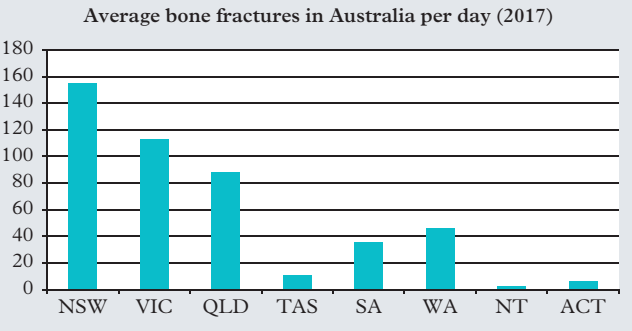


Figure 4 Average bone fractions in Australia per day (2017)

12.8 The respiratory system exchanges gases

In this topic you will learn that:

- the respiratory system is responsible for providing oxygen needed for cellular respiration
- organs of the respiratory system include the pharynx, larynx, trachea, bronchi and lungs.

pharynx
the throat that connects the mouth to the oesophagus

trachea
the large tube that connects the throat to the bronchi; carries air in and out of the body

bronchi
the air passages that carry air in and out of the lungs; airways

alveoli
tiny air sacs in the lungs where gas exchange occurs

Breathing and respiring

When we breathe, we are inhaling oxygen from the air. This passes down the trachea, the bronchi, the bronchioles and finally into the alveoli sacs of the lungs, which is where the oxygen finally passes into our blood.

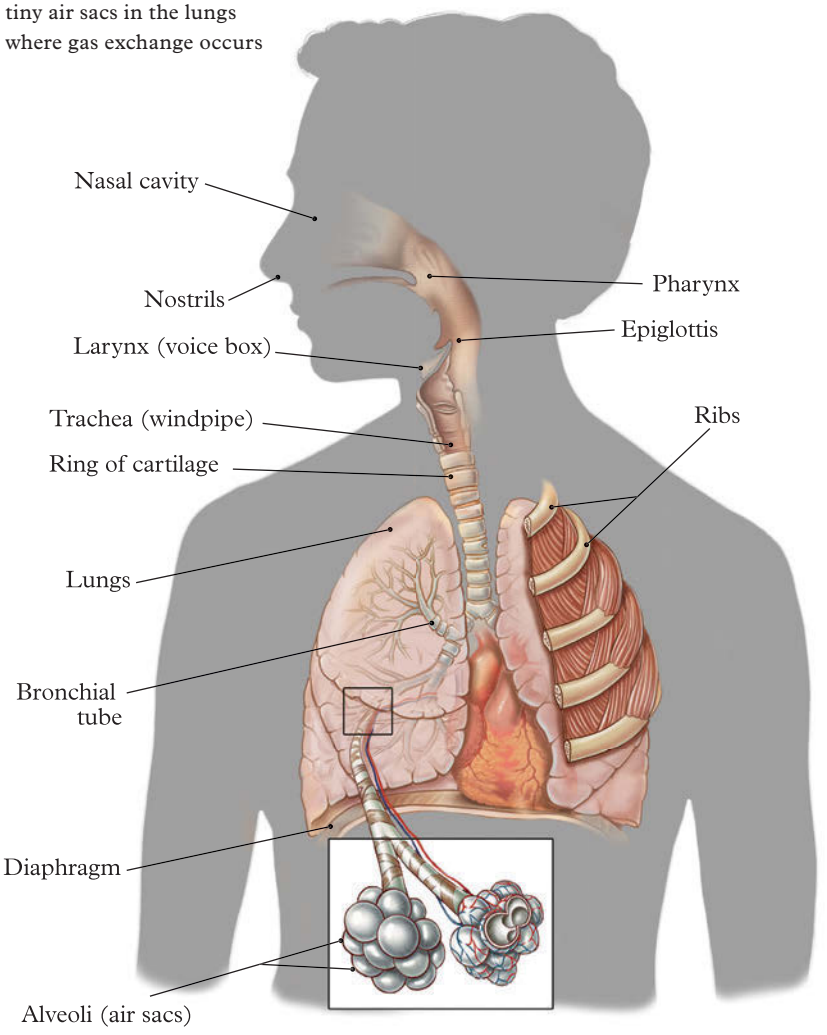


Figure 1 The structure of the respiratory system

While related, it is important not to confuse breathing with respiration. Breathing is the physical action of inhaling and exhaling air. Respiration is the chemical reaction in which oxygen and glucose react to produce carbon dioxide, water and energy.

Every cell in our body requires oxygen in order to carry out cellular respiration and produce energy for our survival. Carbon dioxide, a waste product of cellular respiration, must be transported from the cells back to the respiratory system for removal. This transport occurs via the circulatory system.

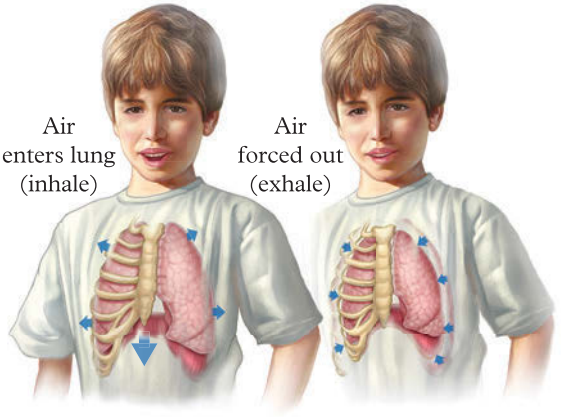


Figure 2 Inhalation and exhalation

Where does the air go?

We breathe air in through our nose and mouth, trapping all the dust and pollens with hairs and wet surfaces as it travels to our throat or **pharynx**. At the bottom of the pharynx is a trapdoor called the epiglottis that controls the passage of food and air. Food goes down the oesophagus to the stomach. Air needs to go down the **trachea** to the lungs.

CHALLENGE
12.8A: Measuring your lung capacity
Go to page **389**.

INVESTIGATION
12.8B: Fish dissection
Go to page **390**.

The lungs

There are two lungs in our chest, which inflate and deflate with every breath we take. The trachea branches into tubes called **bronchi**. The lungs feel spongy to touch because they are home to millions of tiny air sacs called **alveoli**. If these air sacs were unravelled and flattened, they would have a surface area of approximately half the size of a tennis court. Each tiny alveolus is covered by a mesh of even smaller blood vessels called capillaries.

The lungs are structured to have as many alveoli in close contact to as many capillaries as possible. This increases the surface area over which gas exchange can occur.

Oxygen moves into the blood, whereas carbon dioxide (the waste product of cellular respiration) moves out of the blood.

The diaphragm

The **diaphragm** is a dome-shaped muscle that is attached to your ribs and moves up and down beneath your lungs. The muscle contracts down and relaxes up. The diaphragm also separates the heart and lungs from the stomach and digestive system. The lungs have no muscle tissue, so they can't move on their own. Every time you breathe in, the muscles in the diaphragm and between the ribs work together to expand your chest. This creates suction that opens the lungs, pulling air in. Then the muscles relax, allowing the air to move out again.

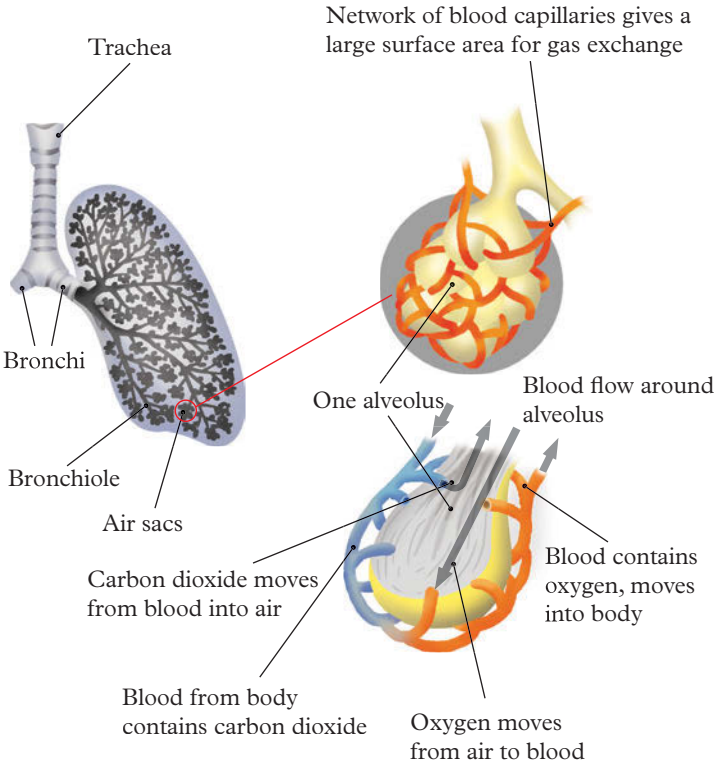


Figure 3 Gas exchange in the alveoli

diaphragm
the dome-shaped muscle that is attached to ribs and moves up and down beneath the lungs

Check your learning 12.8

Recall and describe

1. **Recall** the names of the organs of the respiratory system.
2. **Construct** a simple diagram of the respiratory system, showing how air travels from the mouth and nose to the alveoli.
3. **Explain** the term 'gas exchange'.
4. **Identify** the sequence of steps in breathing in and breathing out.

Apply and analyse

5. **Distinguish** between breathing and respiration.
6. What advantage does the large surface area of the alveoli have in allowing the oxygen to pass into the blood?

Evaluate and create

7. We breathe without making a conscious effort. **Propose** what changes in the blood might be the triggers to make the body subconsciously start to breathe faster or deeper.
8. **Investigate** a disease of your choice associated with the respiratory system. **Summarise** how the disease affects normal function and what can be done to treat, prevent or manage the condition.

Skills builder: Problem solving

9. Complete the cause-and-effect table. (THINK: How does the respiratory system function?)

Cause	Effect
	A person chokes on food in their trachea.
A person's diaphragm is not working properly.	

12.9 Fertilisation produces new life

In this topic you will learn that:

- fertilisation occurs when the female gamete (egg) meets the male gamete (sperm).

The vast majority of animals reproduce sexually. They are also sexually dimorphic, which means that the males look physically different from the females. For baby animals to be born, there needs to be fertilisation of an egg by a sperm. This could happen inside the female or male (internal fertilisation) or out in the open (external fertilisation).

The human male reproductive system

In fertilisation, a gamete from the father (sperm) must meet the gamete from the mother (egg or ovum). The sperm is produced in special organs called the testes. The testes are also responsible for producing a male chemical messenger called **testosterone**.

In most animals, the two testes are kept outside the body in a sac called the scrotum. This is to keep the sperm cooler than the 37°C of the rest of the body. If sperm get too hot, they will not be able to fertilise an egg.

Once sperm are produced in the testes, they move to the epididymis to mature. When necessary, the epididymis contracts (squeezes tight), and the sperm is moved into the vas deferens. Sperm need energy to be activated. Seminal vesicles are small pouch-like structures that provide a sugary fluid called semen that is needed for the sperms' journey along the vas deferens tube to the prostate gland. The prostate gland is a walnut-sized structure that blocks the flow of urine so that the sperm can move along the urethra and be ejaculated out through the penis. The function of the penis is to help the sperm reach the eggs.

oestrogen
a hormone that promotes the development and maintenance of female characteristics of the body

testosterone
a hormone that stimulates development of male secondary sexual characteristics

ovulation
the release of an egg from an ovary

foetus
the unborn offspring of an animal that develops from an embryo

menstruation
the cycle involving the release of the egg and preparation of the uterus for pregnancy

gestation
the length of time between fertilisation and birth

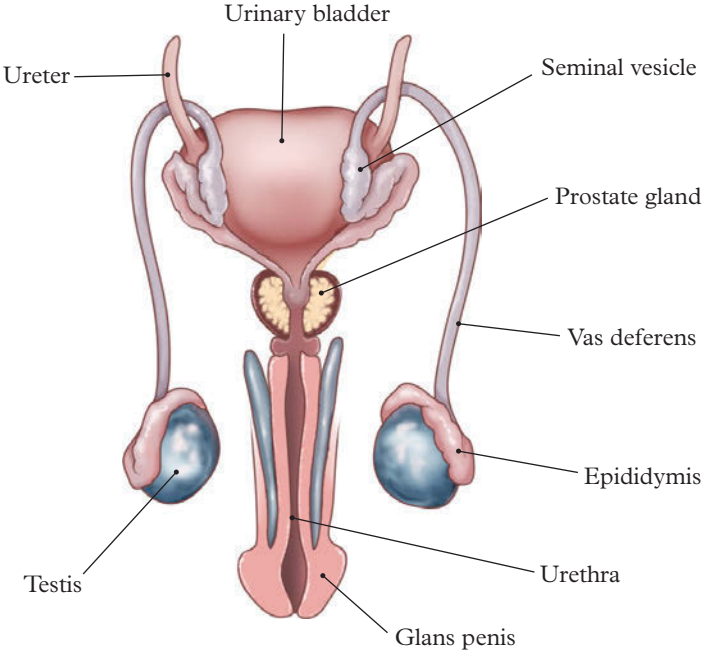


Figure 1 Human male reproductive system

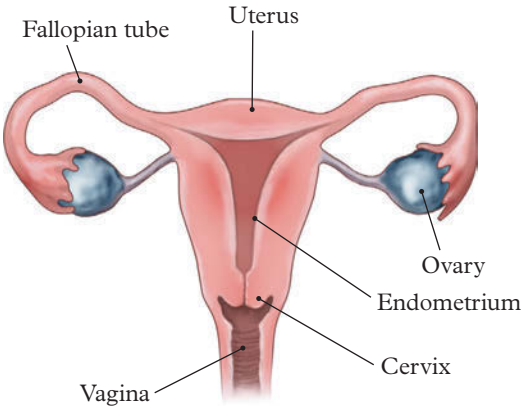


Figure 2 Human female reproductive system

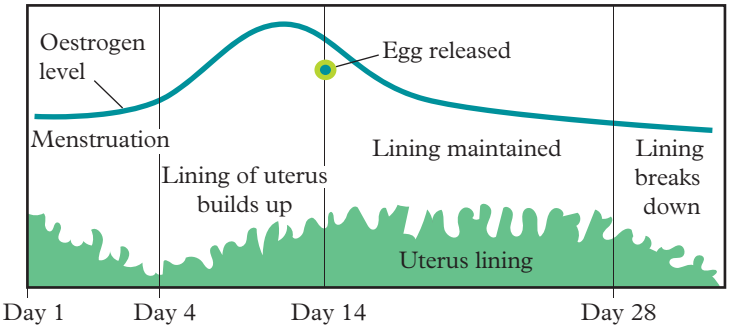


Figure 3 During the average 28-day menstrual cycle, ovulation occurs at day 14.

The human female reproductive system

Human females are born with hundreds of thousands of eggs (or ova) partially formed in their ovaries. Once puberty is reached, every month a chemical messenger from the brain (**oestrogen**) causes one egg to mature and be released. This process is called **ovulation** (see Figure 3).

The egg travels down the fallopian tubes to the uterus. If sperm are present in the fallopian tubes, the egg can be fertilised. In the three to five days it takes for the egg to travel the fallopian tubes, the lining of the uterus (the endometrium) becomes thicker. This is to provide a safe place for the fertilised egg (or zygote) to attach and grow into a **foetus**.

If the egg is not fertilised, the endometrial lining will break down and, two weeks after ovulation, will pass through the cervix and as a period. This monthly cycle is called **menstruation** (see Figure 4).

Menstruation usually starts in females between the ages of 11 and 15; however, it can start before 10 years for some girls and as late as 16 for others. It can take up to 2 years for menstruation to become a regular cycle. The average length of the cycle is 28 days, but it can vary from 23 to 35 days.

If the egg is fertilised and develops into a zygote, it attaches to the thick endometrial layer. A special organ called the placenta forms between the foetus and the uterus. The placenta allows the mother to pass oxygen and nutrients to the developing foetus. The length of time between fertilisation and birth is called **gestation** (pregnancy). In humans, gestation takes nine months.

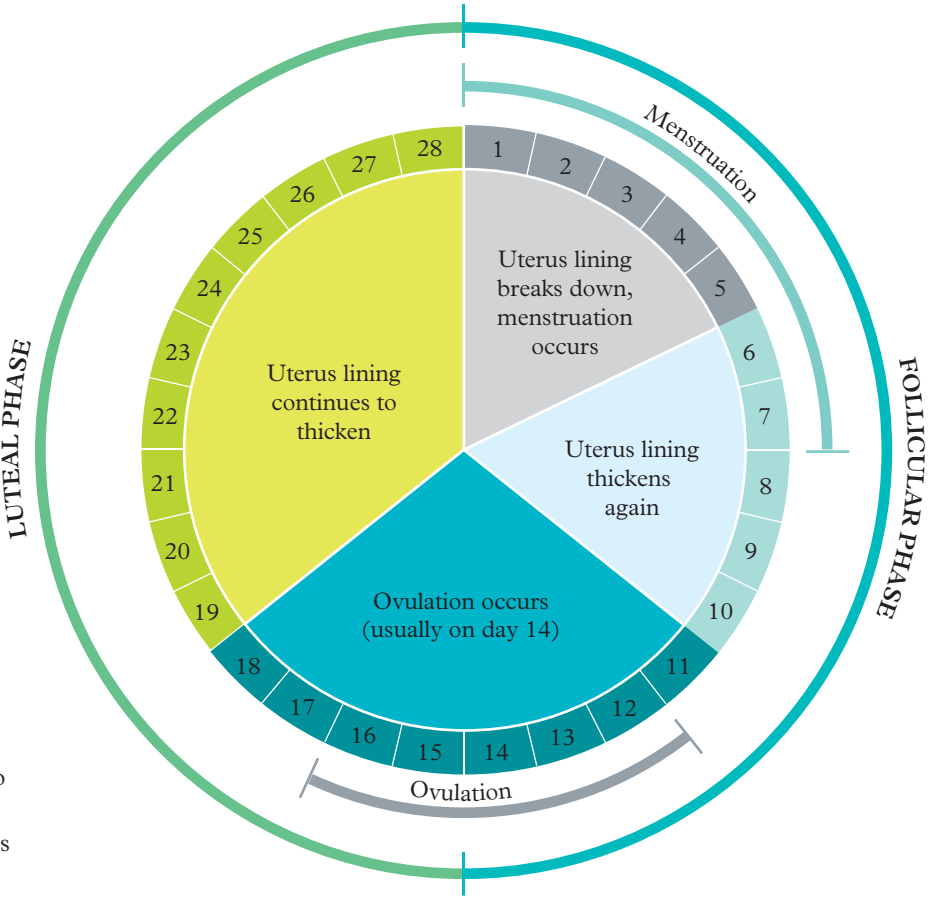


Figure 4 The menstrual cycle begins on the first day of a period.

Childbirth

Humans go through three stages when giving birth. The first stage involves the muscular walls of the uterus contracting, gently squeezing the baby down against the cervix. This causes the cervix to flatten and start dilating (opening). The cervix must open 10 centimetres before the baby's head can move through the vagina. This is the second stage of birth. When born, the baby is still attached to the placenta (which is inside the mother) via the umbilical cord. When the umbilical cord is cut, it will form the belly button on the baby. The third and final stage of birth is the delivery of the placenta. This is important to prevent infections from developing in the uterus.

Fertilisation in different species

Mammals, such as humans, use internal fertilisation and the mother is responsible for nurturing the growing foetus until it is ready to face the world. Placental mammals, like humans, keep the foetus in the uterus for this period whereas marsupial foetuses, such as those of the koala, crawl into the pouch for the final stages of development.

Monotremes, a very rare group of mammals that consists of the platypus and the echidna, lay leathery eggs.

All mammals suckle their young with highly nutritious milk from the mother to give them the best start in life.

Like monotremes, reptiles and birds lay internally fertilised eggs. Reptile eggs are leathery, whereas bird eggs have a hard shell. The eggs contain all the nutrients the foetus needs to develop fully, which is really important for reptiles because most reptiles leave their babies to fend for themselves.

Amphibians and fish generally practise external fertilisation. This usually involves the female laying the eggs in the water and the male coating them with sperm. Often hundreds of eggs are laid at once so there's a greater chance some will survive – they make a tasty snack for passing predators! Some parents will keep watch to ward off predators.

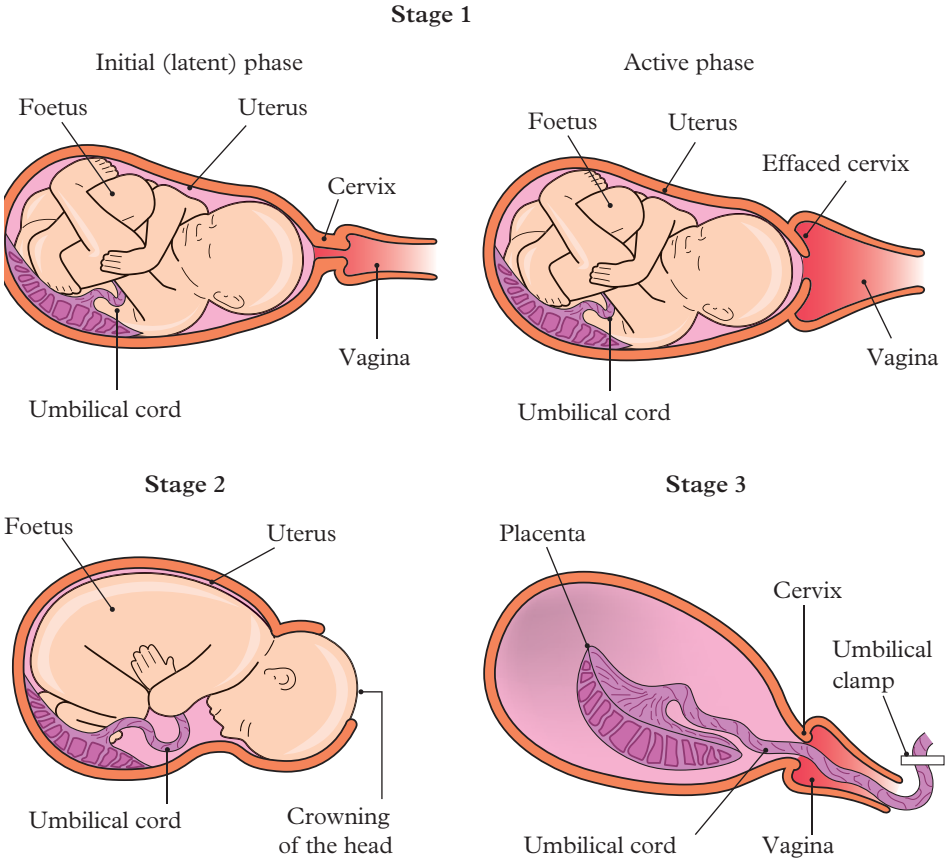


Figure 5 The three stages of childbirth





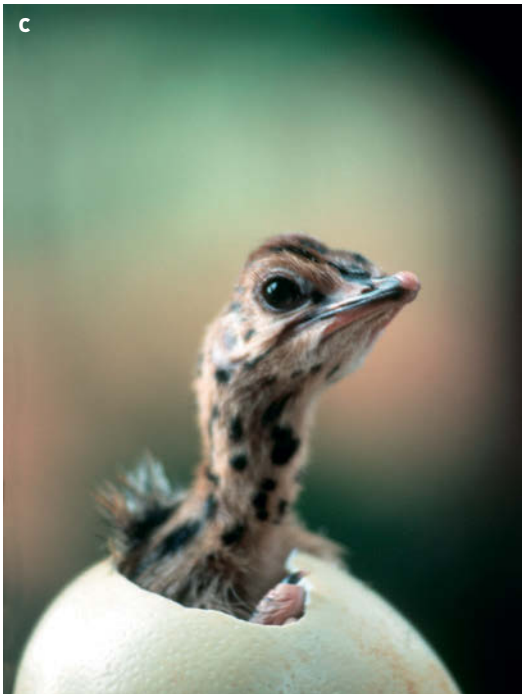


Figure 6 a Marsupial foetuses finish developing in the pouch. **b** Reptile eggs are leathery while **c** bird eggs are hard.

Invertebrates making babies

Invertebrates account for approximately 95% of all animals, so it's not surprising that their reproductive strategies vary quite a lot. Arthropoda, the group that includes insects, spiders and crustaceans, is the largest group of invertebrates.

Terrestrial (land) arthropods generally favour internal fertilisation because of the harsh conditions they often live in. Sometimes the sperm is transferred directly into the female's oviduct (similar to the vagina) and sometimes the sperm is packaged for delivery to the female in more complex ways. Most arthropods will then lay their eggs. Insects and crustaceans tend to hatch as larvae; spiders, as miniature adults.

Check your learning 12.9

Recall and explain

1 **Identify** where fertilisation occurs in the human female reproductive tract.
2 **Explain** menstruation.
3 **Identify** the three stages of childbirth.
4 **Recall** what day in the average cycle ovulation occurs.
5 **Recall** the role of the prostate.

Apply and analyse

6 **Distinguish** between internal and external fertilisation.
7 A student said that a baby girl already had all her eggs intact when she was born. Are they correct? **Explain** your reasoning.
8 If fertilisation occurs, female oestrogen levels will remain high and no more eggs will be released. Why do you think this is?
9 Why would terrestrial invertebrates fertilise their eggs internally?
10 Which two vertebrate classes lay leathery eggs?

Evaluate and create

11 **Propose** a reason for why animals that practise external fertilisation would usually lay large numbers of eggs.
12 Research a range of animals and **construct** a table to show their differences in the gestation period. **Explain** any possible differences you observe.

Skills builder: Communicating

13 Create a flow chart that shows the journey of an ovum (egg) from fertilisation to birth. (THINK: How many steps are involved? Make sure you communicate the whole process.)

12.10 Cells divide for repair, growth and reproduction

*

In this topic you will learn that:

- mitosis is a type of cell division for growth and repair that produces identical daughter cells
- meiosis is a type of cell division required to produce genetically different daughter cells (gametes) necessary for sexual reproduction.

Video
Cell division

somatic cells
all body cells except for gametes

mitosis
the process of cell division to provide growth or repair

meiosis
the process of cell division in which gametes are produced

parent cell
the cell from which other cells develop during cell division

daughter cell
a cell that results from parent cell division

chromosomes
DNA molecules that carry genetic information

Throughout an organism's lifetime, body systems grow and sometimes become damaged and need repair. This means cells need to reproduce so that an organism can increase its size and replace damaged or dying cells. **Somatic cells** refers to all the cells in the body except for the egg and sperm cells (which are called gametes). When somatic cells reproduce, they undergo a process called **mitosis**.

Another type of cell division, called **meiosis**, is crucial for sexual reproduction. Meiosis involves the production of gametes.

Mitosis

As we learnt in chapter 11, mitosis is a type of cell division where one **parent cell** divides to form two genetically identical **daughter cells**. Mitosis occurs in both plants and animals. In humans, the parent cells have 46 **chromosomes** and the daughter cells each have 46 chromosomes. When a cell is ready to replicate, a copy of the chromosomes is made with one set going into each daughter cell.

Mitosis is essential for an organism to grow or repair damage. In humans, cells of the intestinal tract replace themselves every 4 days, skin cells every 3 weeks and bone cells every 10 years. This means the body is constantly undergoing mitosis. Plants that reproduce by vegetative reproduction (see topic 12.3) are also reproducing by mitosis.

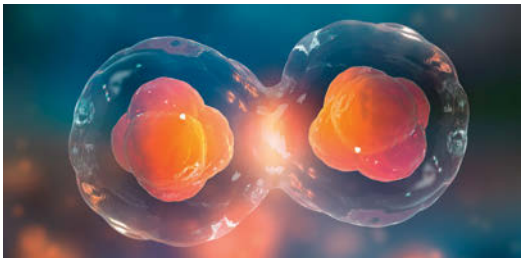


Figure 1 Cells divide into identical daughter cells.

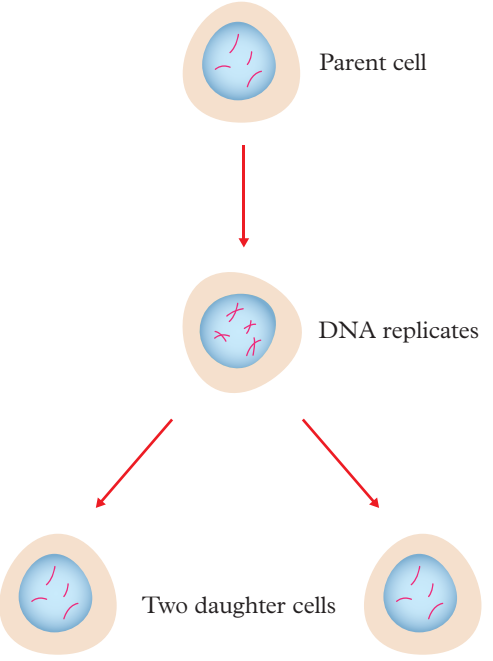


Figure 2 A simplified representation of mitosis

Meiosis

Half of the genetic material in each of your cells comes from your mother, and the other half comes from your father. Have you ever wondered how the genetic material in one of your parent's cells divided in half?

A gamete is a sex cell. In animals, the male gamete is a sperm and the female gamete is an ovum. In flowering plants, the male gamete is contained in a pollen grain and the female ovum is located in the flower's ovary. The male and female gametes of a species join to form the first cell of the offspring.

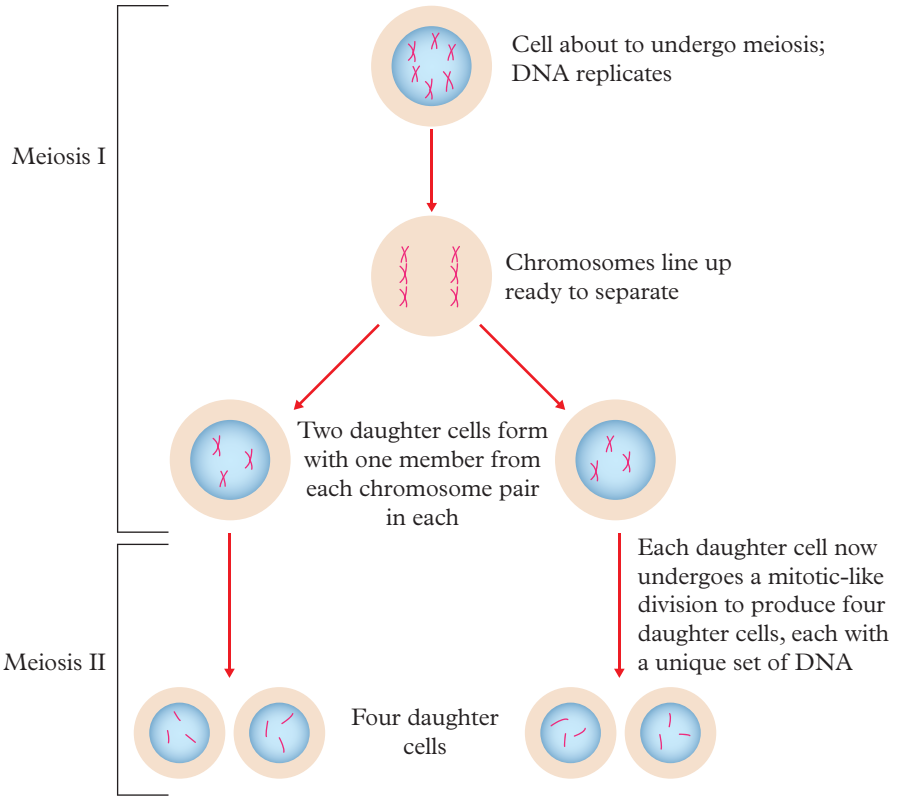


Figure 3 The process of meiosis



Figure 4 When a haploid sperm cell (*n*) fertilises a haploid egg cell (*n*), a diploid somatic cell (2*n*) is formed.

Gametes differ from all other body cells because they contain half the number of chromosomes of somatic cells – they are **haploid**. Most somatic cells in your body contain 46 chromosomes arranged in pairs (two sets of 23 chromosomes, or 2*n*) – they are **diploid**. Gametes (egg and sperm) in humans have 23 chromosomes (*n*). When the egg and sperm combine at fertilisation, a diploid somatic cell is produced – one set of 23 chromosomes comes from the mother and one set of 23 chromosomes comes from the father. In this way, all children are similar, but not identical, to their parents (see Figures 3 and 4).

haploid
(of a cell or nucleus) having a single set of unpaired chromosomes (*n*)

diploid
(of a cell or nucleus) having a set of paired chromosomes (2*n*)

Check your learning 12.10

Recall and explain

1 **Explain** why cells undergo mitosis.
2 **Define** the term 'gamete'.
3 **Recall** what is meant by vegetative reproduction and give an example.

Apply and analyse

4 Are the offspring of sexually reproducing organisms identical to their parents? **Explain**.
5 **Contrast** a haploid cell and a diploid cell. Give an example of each.
6 A cell that is about to undergo mitosis must double its amount of DNA. **Explain** why this needs to occur.
7 **Explain** why is it essential that the number of chromosomes is halved during meiosis.
8 **Describe** the difference between a foetus and a baby.

Evaluate and create

9 **Evaluate** the importance of the daughter cells having identical genetic material to the parent cell during mitosis.

Skills builder: Processing and analysing

10 A cell growing in a Petri dish divides into two identical daughter cells. These two identical daughter cells divide again to make four cells. The four cells undergo mitosis again to create eight cells.

Construct a graph that represents the number of cells present in the Petri dish after each cell division takes place. (THINK: What kind of graph is most appropriate for this information? You might like to look at chapter 1 to help you decide.)

*REVIEW

Multiple choice

1 **Identify** which body system removes wastes.
- **A** Respiratory system
- **B** Circulatory system
- **C** Digestive system
- **D** Excretory system

2 Where does photosynthesis occur in a plant cell?
- **A** Mitochondria
- **B** Chloroplast
- **C** Nucleus
- **D** Cytoplasm

3 **Identify** what type of cell division is required for reproduction in humans.
- **A** Cross-pollination
- **B** Mitosis
- **C** Meiosis
- **D** Binary fission

Recall and explain

4 **Recall** the word equation for:
- **a** photosynthesis
- **b** cellular respiration.

5 **Identify** the two organ systems of plants.

6 **Identify** the correct labels for plant structures a–d in Figure 1.

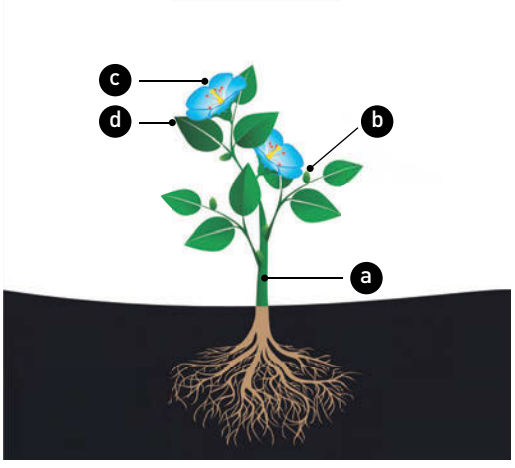


Figure 1 Plant

7 **Explain** the process of digestion and how subsequent nutrients are absorbed through the walls of the small intestine.

8 **Explain** one example where a large surface area is essential to the functioning of a human organ.

9 **Identify** four things that the circulatory system transports around your body.

10 **Describe** the function of the liver.

11 **Recall** the gaseous waste product removed by the lungs.

12 **Recall** the three types of muscle cells and where they can be found.

13 **Recall** the structure that attaches muscles to bones.

14 **Identify** the type of cell division that results in the formation of sperm and ova.

15 What is the scientific term for 'making new organisms'?

16 **Recall** what gas is passing out of the blood back into the lungs, at the same time that oxygen is passing into the blood.

Apply and analyse

17 **Compare** the reactants and products for photosynthesis and cellular respiration. What do you observe?

18 What system in humans would provide the same function as a plant stem? **Explain** your response.

19 **Compare** the similarities between your excretory system and your respiratory system.

20 Would a skin cell or a muscle cell contain more mitochondria? **Explain** your answer.

21 Mangrove trees get rid of excess salt through their leaves. This salt is often seen as white crystals on the underside of the leaves. Which system does this represent for the plant? How is this similar to humans? Which organ(s) is responsible for this in humans?

22 **Distinguish** between voluntary and involuntary muscle movement.

23 Would you expect to find chloroplasts in the roots of a plant? **Explain**.

24 **Construct** a labelled diagram to **contrast** the process and purpose of mitosis and meiosis.

25 A girl was keeping a record of her menstrual cycle. She found her cycle lasted approximately 28 days. If her last period started on 1 June, determine the following.
- **a** **Identify** when she will ovulate.
- **b** **Identify** when her next period will start.

26 **Explain** why muscles would need more blood during exercise.

27 **Identify** the body system from which the circulatory system absorbs nutrients.

Evaluate and create

28 Which of the body's systems are necessary for cellular respiration to occur? **Justify** your answer.

29 A student observes a small yellow flower that doesn't appear to have a scent. What is the most likely type of pollinator? **Justify** your answer.

30 Use your understanding of the different systems of the human body to create a concept map detailing the connections between the systems.

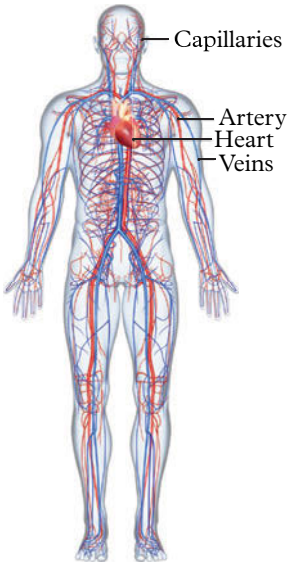


Figure 2 The human body is made up of systems.

31 Imagine it is your job to construct a 'user's manual' for one of the systems covered in this chapter. Write a list of 10 'Frequently Asked Questions' (FAQs) to go at the front of the manual. Write an answer to as many of your questions as you can. If you don't know the answer, write down where you could find the answer or who you could ask.

32 The Waratah is an Australian native plant with a woody stem and large, bright-red flowers. What is the most likely pollinator? **Justify** your answer.



Figure 3 Waratah

33 **Describe** how skeletal muscles work by contracting and expanding.

Critical thinking

34 Many smoking bans, such as bans in workplaces, are related to the issue of second-hand smoke. This refers to how smoking affects people standing near a person smoking. Find out some facts about the impacts of second-hand smoke. Do you think the rules are required? Argue your position on whether smoking bans should be extended or removed or they are fine as they are now.

35 What do you think would happen to flowers if bees were no longer around to act as pollinators? What about other pollinators? **Justify** your response.

Going further

36 Sweating is often considered to be a bad thing. What do you think? **Construct** an argument for your point of view. What do you think would happen if you didn't sweat?

37 Dissections and research involving animals have contributed significantly to our understanding of the human body. In fact, it would probably be fair to say that we couldn't have come this far without them. Critically **evaluate** the positives and negatives involved in using animals for medical research purposes. **Discuss** your points with a partner and share your thoughts with the class. Do you think animals should continue to be used in medical research?

38 Some reptile eggs are affected by the temperatures they experience while incubating in the nest. For example, within a single nest, the temperature will determine whether the offspring are all male, all female or a mix of both. How might warmer weather as a result of the enhanced greenhouse effect impact on green sea turtle populations?



Figure 4 Green sea turtle eggs produce female babies when the eggs are warmer and male babies when the eggs are cooler.

Research

39 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

»Getting rid of nitrogen

Animals need to get rid of nitrogen. Some animals produce ammonia, some produce uric acid, some produce urea and others produce guanine. Find out which types of animals produce these different substances to remove nitrogen. In which environments do animals that produce ammonia live? In which environments do animals that produce urea live? What are the advantages for animals producing the different forms of nitrogenous wastes?

»Seed banks

A seed bank stores a large variety of seeds in case a particular species of plant is placed at risk as a result of natural disaster, outbreaks of disease or war. Research a major seed bank near your school. What type of seeds do they collect? Who collects the seeds for the bank? How are they collected? What conditions are needed for the seeds to remain viable (alive)?

»Omega-3 fatty acids

What are omega-3 fatty acids? What foods should be eaten to include them in your diet? How do omega-3 fatty acids help reduce heart disease? What other diseases are helped by omega-3 fatty acids? Why is this sort of fat good for you to eat?

»Rh factor

What is the Rh factor? How is the Rh factor written with blood groups? What percentage of the population is Rh negative and what percentage is Rh positive? What effect does the Rh factor have during pregnancy?

»Plant cells

Plant leaves have small pores called stomata, which allow air to pass in and out of the plant. These stomata are made up of two guard cells that can change their shape. Found out how stomata open and close in response to changing environmental conditions. Under what types of conditions are the stomata likely to open? What are the triggers for the stomata to close? How does the shape of the guard cells assist the opening and closing of the pore?

Reflect

Now that you've completed this chapter, reflect on your ability to do the following:

	I can do this.	I can't do this yet.	
Identify the materials required by multicellular organisms for the processes of respiration and photosynthesis.	☐	☐	Go to page 202–203.
Explain that the systems in multicellular organisms work together to provide cell requirements, including gases, nutrients and water, and to remove cell wastes.	☐	☐	Go to page 202–203.
Outline the role of cell division in growth, repair and reproduction in multicellular organisms.	☐	☐	Go to page 222–223.
Describe the role of the flower, root, stem and leaf in maintaining flowering plants as functioning organisms.	☐	☐	Go to page 204–207.
Describe the role of the digestive, circulatory, excretory, skeletal/muscular and respiratory systems in maintaining a human as a functioning multicellular organism.	☐	☐	Go to page 208–217.
Outline the role of the reproductive system in humans.	☐	☐	Go to page 218–221.

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HEALTH SCIENCE

How has scientific knowledge and technology improved our health?

13

Have you ever wondered ...

- Why is personal hygiene so important?
- Why does our generation live longer than those before us?
- How does someone survive an organ transplant?

SCIENCE UNDERSTANDING

In this chapter you will learn how to:

- research an example of how changes in scientific knowledge have contributed to finding a solution to a human health issue
- recount how evidence from a scientific discovery has changed understanding and contributed to solving a real-world problem, e.g. animal or plant disease, hygiene, food preservation, sewage treatment or biotechnology
- describe, using examples, how developments in technology have contributed to finding solutions to a contemporary issue, e.g. organ transplantation, artificial joints/limbs, treatment for diabetes, asthma, kidney or heart disease
- give examples to show that groups of people in society may use or weight criteria differently in making decisions about the application of a solution to a contemporary issue, e.g. organ transplantation, control and prevention of diseases and dietary deficiencies.

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Check your Student obook assess for these digital resources and more:

QuizletLive
Compete in teams to test your knowledge.

Assess quiz
Before you start this chapter, assess your science skills.

Check your Teacher obook assess for these digital resources and more:

QuizletLive
Launch a quiz for your students on key concepts in this chapter.

13.1 Scientific knowledge improves human hygiene and health

In this topic you will learn that:

- scientific discoveries have improved hygiene practices, such as handwashing, resulting in better health for society.

We all know to wash our hands after going to the toilet and before eating. We know we should cover our mouth when coughing, and we should definitely avoid drinking water that has been contaminated by faecal matter (poo). To do any of these things incorrectly runs the risk of making people very sick, or worse.

Society did not always have this knowledge, however. Throughout history, scientists have discovered more about the link between hygiene and health.

The science of handwashing

In 1846, Hungarian doctor Ignaz Semmelweis (1818–1865) noticed a strange phenomenon at the hospital he was working at. There were two maternity wards in the hospital. In one ward, male medical students delivered babies. In the other ward, midwives delivered babies. Semmelweis realised that a lot more women were dying in the ward run by medical students, and he wanted to know why.

Semmelweis observed that the medical students often delivered babies in the hospital after they had been conducting surgery or performing autopsies on corpses. The midwives did not conduct surgery or autopsies. Semmelweis proposed a theory that the medical students were transferring contagious 'particles' from the corpses to the women on their hands. So he made a rule that all medical staff had to wash their hands with a chlorine solution. He chose chlorine solution because it got rid of the smell of corpses, but today we understand that it's also a very effective disinfectant. When the staff washed their hands, the rate of deaths fell dramatically.

Resource
STEM activity: How clean are your hands?



Figure 1 Ignaz Semmelweis made his medical staff wash their hands to prevent patients from dying in hospital.

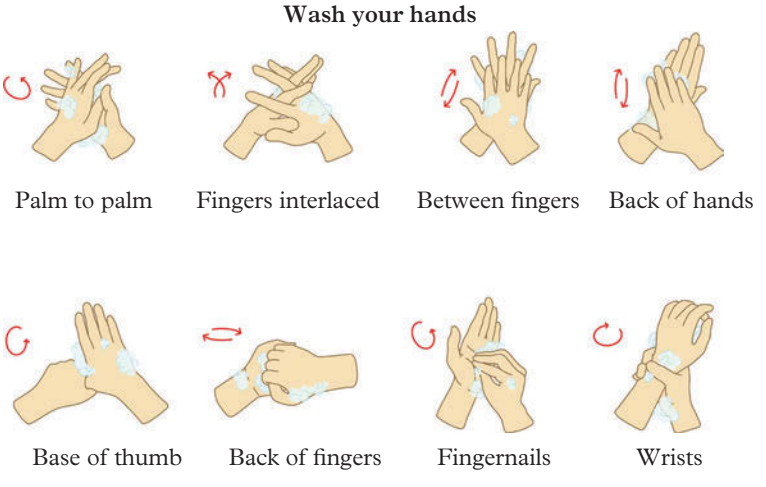


Figure 2 Washing hands properly takes soap and water over the whole hand, fingers and wrists.

Sadly, even though Semmelweis was correct, he was not very well liked and his ideas were rejected by the scientific community at the time. But because of scientists like Semmelweis, we now understand that washing our hands with soap is one of the best ways to stop the spread of disease and to stay healthy.

The importance of plumbing

Plumbing is only a relatively recent invention. For many centuries, people did not realise the danger of collecting drinking water from the same water supply that was contaminated with sewage.

In 1854, English doctor John Snow (1813–1858) made a very important realisation about the outbreaks of cholera around particular drinking wells in London. Snow observed that the disease outbreaks spread faster where people were drinking sewage-contaminated water. When the wells were closed down, the cases of cholera dropped. While he was unable to determine what pathogen caused cholera, Snow's ideas helped later scientists to link the disease to a specific bacterial pathogen. It is through this accumulation of scientific knowledge that we now have water treatment processes, including the addition of chlorine to water to kill pathogens.

The discovery of germs

Up until the late 1800s, people believed that sickness was randomly caused by 'miasma' – a harmful mixture of 'bad air' and decomposed matter. They thought that not much could be done to avoid disease apart from avoiding the bad air. But in 1862, French scientist Louis Pasteur (1822–1895) conducted an experiment that provided evidence that disease was not a spontaneous occurrence. Pasteur's **germ theory** stated that microbes were airborne and that each infectious disease was caused by a specific pathogen.

This scientific knowledge is responsible for hygiene practices such as covering your mouth when coughing, storing food and drink at the correct temperature and cooking food, particularly meat, to the appropriate temperature.

germ theory
the theory that diseases are caused by microbes called germs



Figure 3 John Snow realised that drinking water contaminated by sewage was unhealthy.



Figure 4 John Snow mapped outbreaks of cholera around the area of Soho and found they were occurring around contaminated wells.

Check your learning 13.1

Recall and explain

1 **Explain** why it was important for society to discover germs. How has it improved health science?

2 **Recall** the best way to wash your hands and **explain** why it is important.

Evaluate and create

3 **Investigate** how scientific knowledge about one of the following helped to find a solution to a health problem.

- Hand washing
- Food hygiene
- Sewage treatment plants

Create a short presentation to **explain** the science behind the particular discovery and how it has helped society.

Skills builder: Planning investigations

4 **Consider** the variables in Snow's investigation of cholera outbreaks.

a **Identify** the dependent variable.
(THINK: What was he measuring?)

b **Identify** the independent variable.
(THINK: What was he comparing?)

13.2 The discovery of penicillin saves lives

In this topic you will learn that:

- the discovery of penicillin changed our understanding of bacterial growth and disease.

It has been accepted for over 3000 years that some moulds could kill infection. The discovery of the chemical that was responsible for this is attributed to Scottish physician Alexander Fleming (1881–1955).

Discovering penicillin

In 1928, Fleming was trying to grow bacteria on special agar plates as part of his research. Bacteria usually grow very well across the top of agar plates. Usually the agar plates are kept at 37°C so that the bacteria can easily grow. However, on this occasion, Fleming failed to clean up after his experiment and left an agar plate open on his bench before leaving for a holiday. When he returned, a small spot of mould had started growing in the centre of the plate. All around the mould was a clear circle where the bacteria were unable to grow. Fleming concluded that the mould (*Penicillium*) was producing a molecule that prevented the bacteria from growing. The molecule, which was named penicillin, had the ability to stop bacterial growth by preventing the bacteria repairing or making a new cell wall.



Figure 1 Some moulds are able to prevent bacterial growth.

Producing penicillin

It took ten more years and the work of Australian pathologist Howard Florey (1898–1968) and German-born British chemist Ernst Chain (1906–1979) to develop a method of isolating penicillin and producing it on a large scale. They were part of a team of specialists brought together to grow the mould, extract the penicillin, purify it and trial its treatment on patients.

The researchers' most important experiment occurred in May 1940. Eight mice were infected with streptococci bacteria, and four mice were treated with the newly extracted penicillin. These four mice survived while the mice without the penicillin died.

This led the researchers to trial the penicillin on their first patient, Albert Alexander, whose whole face was swollen after being scratched by a rose thorn. One eye had been removed while the other had been lanced to drain the pus. Within one day of being given penicillin, Albert's health started to improve. Unfortunately, Fleming's group did not have enough penicillin to finish the treatment and the patient suffered a relapse and died. As a result the researchers tried treating children as smaller doses could be used and the treatment could last longer (see Figure 2). Eventually their purification methods and resulting treatment were successful. They were awarded the Nobel Prize in Physiology or Medicine in 1945 for their work.

The use of penicillin as an antibiotic revolutionised health care and the lives of many people who, without such treatment, would have died from bacterial infection.

There are now many more different antibiotics available, most of which are extracted from fungi. The overuse of

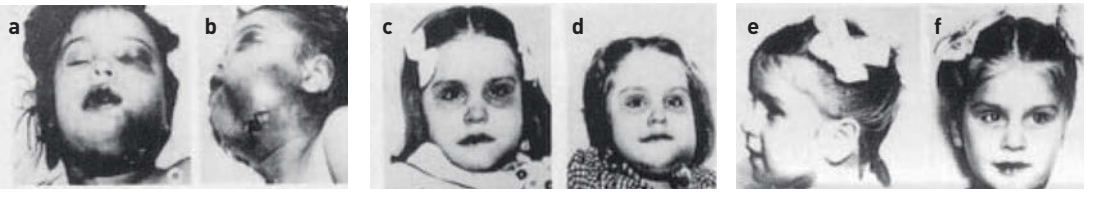


Figure 2 These photos from 1942 show the improvement of a child after penicillin treatment for a bacterial infection: **a**, **b** before treatment; **c** four days after treatment; **d** nine days after treatment; **e**, **f** fully recovered.

antibiotics is a cause for concern within society, however. Due to the rapid rate at which bacteria reproduce, some strains of bacteria are becoming 'resistant' to treatment – that is, they are not affected by antibiotics. Scientists are continually searching for new types of natural and artificial antibiotics to treat these new 'superbugs' that are resistant to all types of antibiotics.

A dose of antibiotics not only destroys the harmful bacteria but also the good bacteria in your body. Therefore, antibiotics should only be used to treat bacterial infections when absolutely necessary.



Figure 4 Ernst Chain



Figure 3 Howard Florey

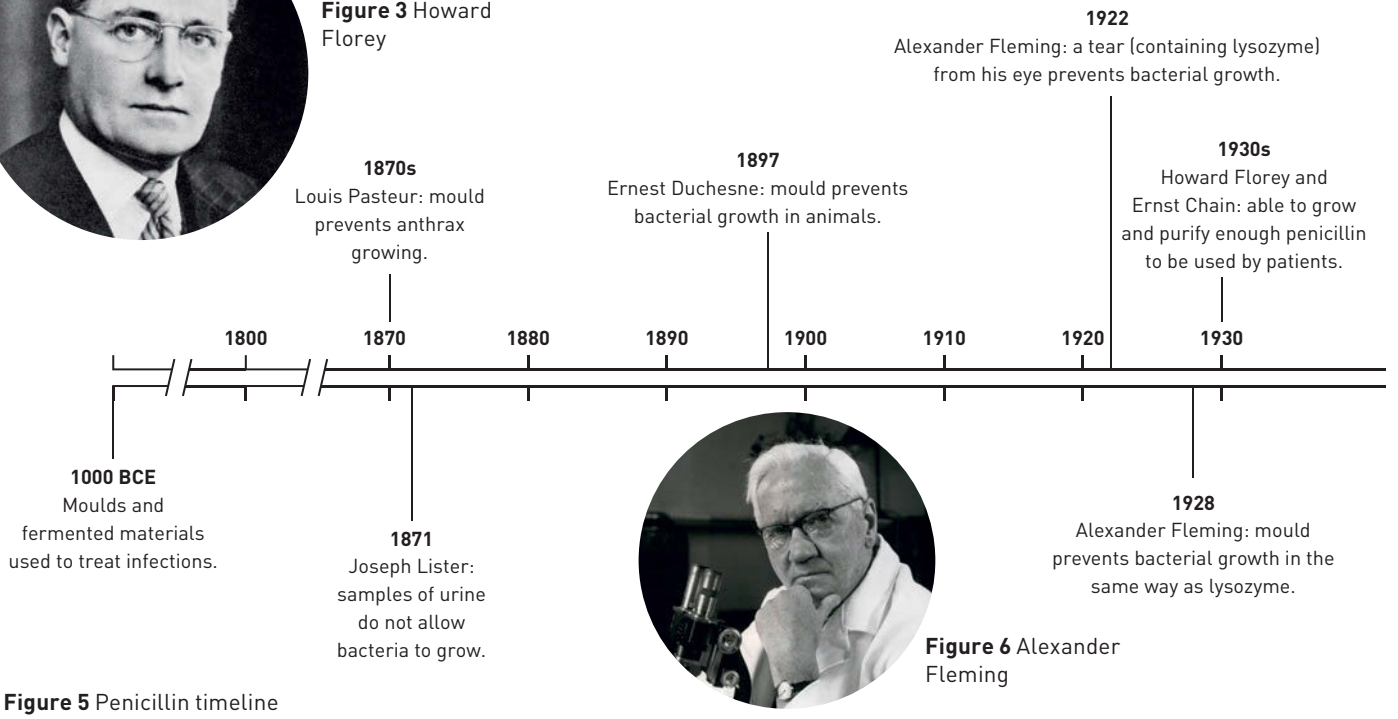


Figure 5 Penicillin timeline

Figure 6 Alexander Fleming

Check your learning 13.2

Recall and explain

1 What is penicillin?

2 **Recount** how the discovery of penicillin contributed to solving a real-world problem.

Apply and analyse

3 **Explain** why Florey and his group of scientists did not give penicillin to four of their mice.

4 Many of our medicines today originate from the molecules made in nature. How does the purity of penicillin prepared in a laboratory compare with the fermented materials used in 1000 BCE?

5 **Analyse** the penicillin timeline in Figure 5. How did Florey and his team build on the discoveries of the scientists that came before them?

Evaluate and create

6 'The most exciting phrase to hear in science, the one that heralds discoveries, is not "Eureka" but "that's funny"'.

Use Fleming's discovery to **discuss** this quote from Isaac Asimov.

Skills builder: Planning investigations

7 Using the information in this topic, summarise the process Fleming followed to produce *Penicillium* as a logical procedure. (THINK: What are the key features of a method?)

13.3 Science solves health problems

In this topic you will learn that:

- scientific discovery helps to solve health problems in our body systems.

At the start of the 1900s, the average life expectancy of an Australian male was 55 years and 59 years for a female. One hundred years later, those life expectancies had increased to 78 for men and 83 for women. Why the increase? Science and technology play a major role.

In chapter 12, we learnt how our body systems all work together to make sure we have everything we need to live. But things can go wrong in any of these systems. When this happens, our understanding of how body systems work helps scientists to solve these health problems.

Problems in the digestive system

The digestive system is just like a production line in a factory. Each organ relies on the previous section working effectively. This unfortunately does not always occur.

Stomach ulcers

For many years, ulcers (small open sores) in the stomach lining were thought to be caused by too much rich food or stress. Patients would come to hospital in a lot of pain from stomach acid burning the tissues around their ulcers.

In the early 1980s, Australian scientists Barry Marshall and Robin Warren noticed that patients who had the symptoms of a stomach ulcer also had the bacterium *Helicobacter pylori* in their stomach. They did a series of experiments to show that the spiral-shaped bacteria caused damage to the cells lining the stomach, forming an ulcer. The definitive proof came when Marshall did something controversial: he swallowed a solution containing the bacteria, which proceeded to give him ulcers. Their discovery meant that ulcers could be effectively treated by antibiotics. In 2005, Marshall and Warren were awarded the Nobel Prize in Physiology or Medicine.

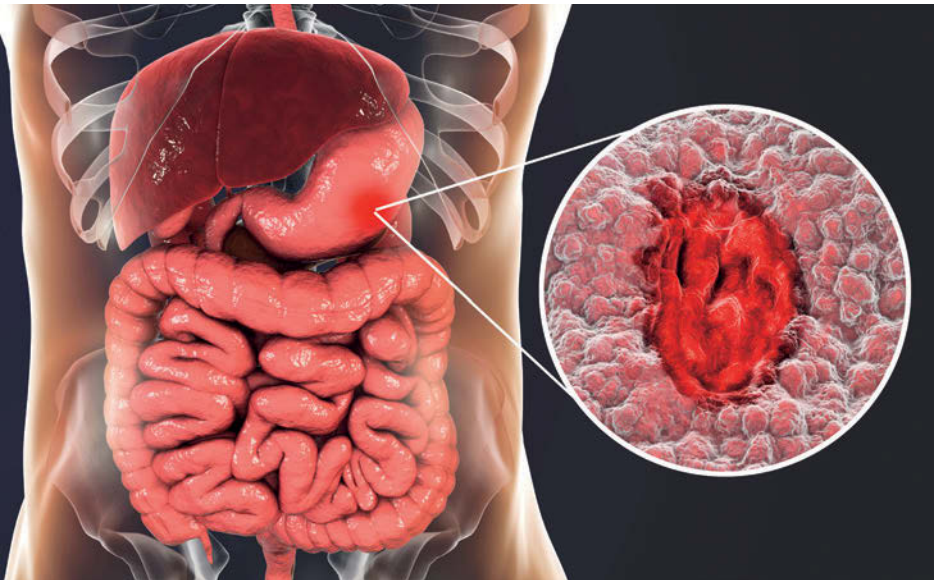


Figure 1 A stomach ulcer



Figure 2 Robin Warren (left) and Barry Marshall (right)

Bowel cancer

Scientific research has given doctors a better understanding of bowel cancer. It has led to a significant increase in our understanding of how the disease works. This has improved prevention, diagnosis and treatment of the disease.

We now know that bowel cancer starts as growths, called polyps, which can be removed before turning cancerous if they are detected early. This can be done via a colonoscopy, which is a procedure allowing a doctor to screen the lining of the bowel using a small camera.

If the polyp has turned cancerous, more high-tech science is used to determine the best course of action. Treatment options include surgery, radiotherapy, chemotherapy and now immunotherapy, where the patient's own body defence systems can be used to target the tumour directly.

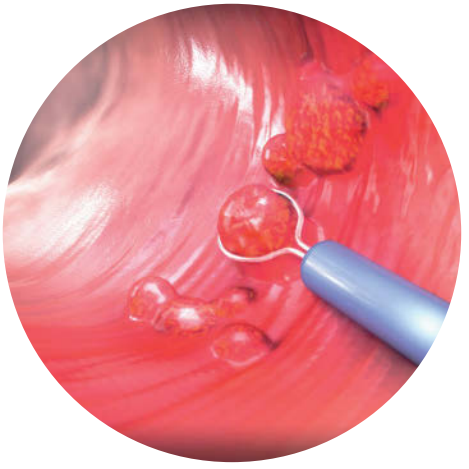


Figure 3 Polyps in the bowel can be detected by a colonoscopy and removed before they become cancerous.

Problems in the respiratory system

Our respiratory system is responsible for supplying the oxygen we need for energy to every cell in the body. When things go wrong, our body struggles to survive.

Asthma

Asthma is quite common in our population, affecting more than one in ten Australians. Asthma usually starts when something in the environment irritates the airways. This causes the bronchi and bronchioles to narrow, making it harder for air to move into the lungs and therefore breathing becomes difficult. Asthma attacks can be reversed by drugs, such as Ventolin. Ventolin works by relaxing the muscles around the airways, making it easier to get more air into the lungs.

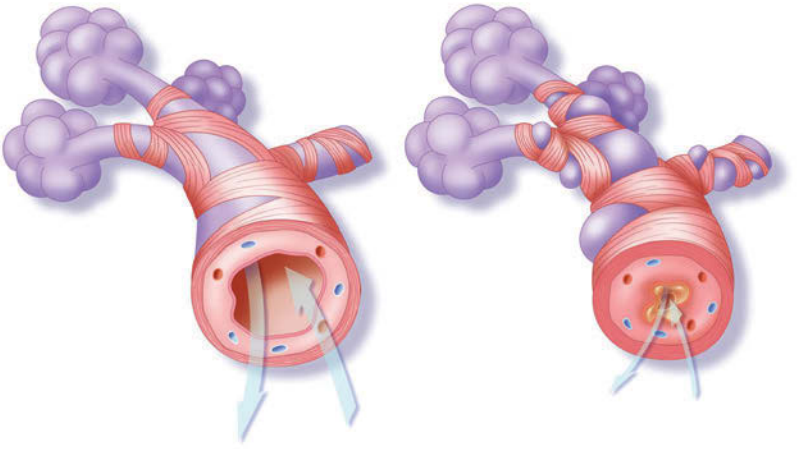


Figure 4 Asthma causes the bronchioles to become narrow: **a** normal airway and **b** asthmatic airway.

Lung cancer and emphysema

Currently there are more than 12 000 new cases of lung cancer diagnosed each year in Australia. The majority of these cases are linked to smoking cigarettes.

Cigarette smoke contains toxic **carcinogenic** (cancer-causing) chemicals and tar. The tar has a honey-like consistency and covers the inside of the alveoli and stops oxygen from moving into the blood. It can also damage the alveoli of the lungs, resulting in a chronic cough and difficulty breathing. This condition is called **emphysema**.

In the early 1900s, people thought smoking was good for their health – even doctors encouraged it. But in the 1950s several studies began to explore the link between smoking and lung cancer. These studies proved that smoking caused lung cancer and was responsible for many other cancers and health issues.

Since 1995, the number of smokers in Australia has almost halved thanks to our understanding of the link between smoking and health problems.

carcinogenic
(a substance that) has the potential to cause cancer

emphysema
a respiratory condition caused by damage to the alveoli

asthma
a respiratory condition that causes the airways to narrow or produce extra mucus

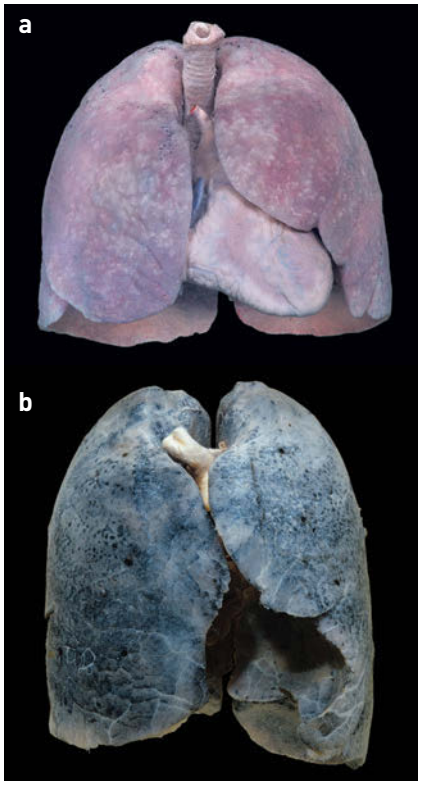


Figure 5 a Healthy lungs; **b** a smoker's lungs

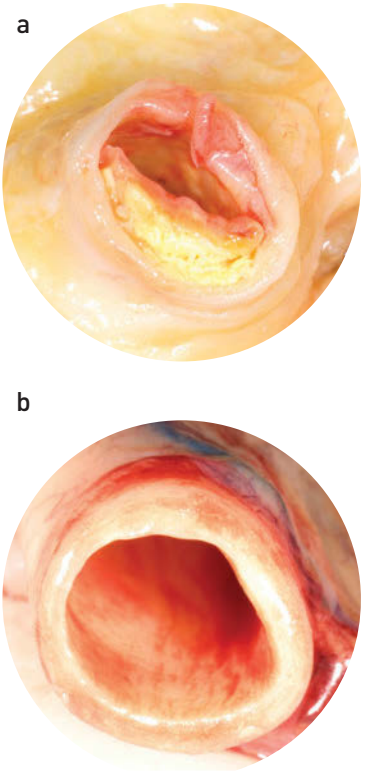


Figure 6 a A blocked artery; **b** an unblocked artery

Problems in the circulatory system

Diseases of the circulatory system are Australia's biggest killer. When the vessels narrow due to fatty build up, nutrients and oxygen cannot be transported around the body. This can lead to tissue death, heart attacks, stroke and death.

Coronary heart disease

A heart attack is usually caused by coronary heart disease (CHD). CHD occurs when fatty deposits block important blood vessels in the heart (see Figure 7). 'Coronary' refers to the heart's own blood vessels. The 'attack' occurs when the vessels become completely blocked, or when a bit of the fatty deposit breaks off and travels through the narrowing vessels until it causes a blockage. Heart muscle cells may be killed in the process.

CHD can be treated in a number of ways, such as by taking medication or improving diet. In 1960, the first heart bypass operation was performed. A bypass operation involves removing a blood vessel from the leg (or other body parts) and using that vessel to 'bypass' a blocked vessel in the heart. In doing so, normal blood flow around the heart is restored and the patient survives. The operation is very invasive to the patient.

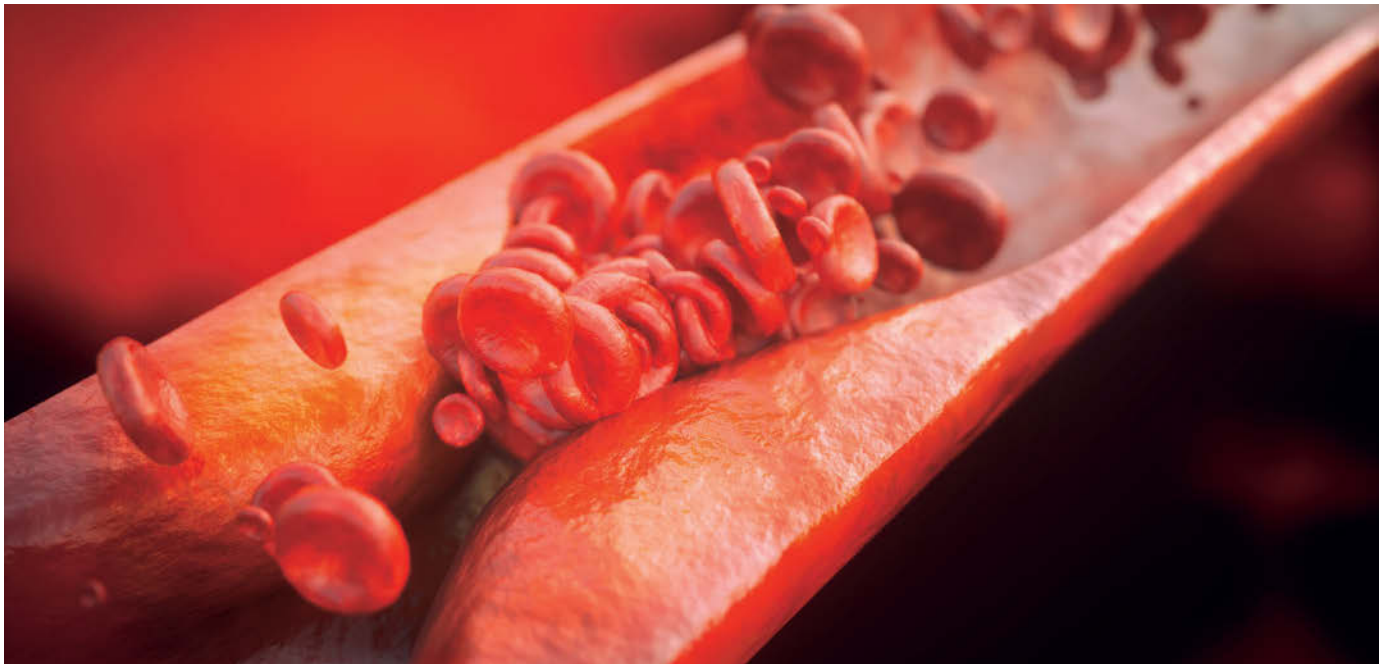


Figure 7 Coronary heart disease occurs when a blood vessel in the heart becomes blocked, restricting blood flow.

Soon after, in the 1980s, the first expanding stents were used (see Figure 8). A stent is a tiny tube that can be inserted into a blood vessel and expanded to keep a passageway open. While still invasive, this procedure only requires day surgery and a small incision (cut) in the groin to insert the stent up into the heart.

Atherosclerosis

Atherosclerosis is a disease that results when blood vessels harden and narrow. It can occur anywhere in the body. The narrowing is caused by a build-up of plaque on the inside of the arteries and veins. Plaque consists of fat, cholesterol and other substances normally found in the blood. Layers of plaque are laid down over time, eventually hardening and restricting blood flow. The symptoms depend on the part of the body affected by the narrowed blood vessel. If the blood vessel is in the heart, a heart attack will follow.

Similar to CHD, treatment for atherosclerosis can include medication or surgery, such as a stent to widen the blood vessels.

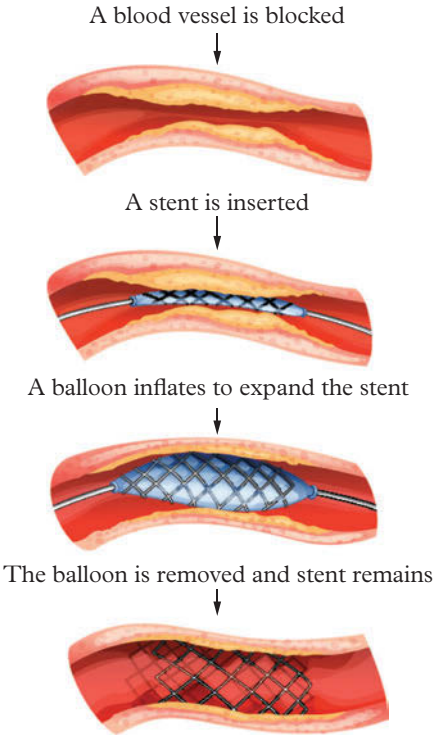


Figure 8 A stent is a plastic or metal tube that can be expanded to keep a vessel open.

Check your learning 13.3

Recall and explain

1 **Recall** one health problem and how science has helped to develop a treatment.

2 **Distinguish** between coronary heart disease and atherosclerosis.

Evaluate and create

3 **Discuss** how our scientific understanding of the circulatory system helped to develop a treatment for coronary heart disease.

4 Do you believe Barry Marshall swallowing a solution containing *H. pylori*, to show the link between the bacteria and stomach ulcers, was ethical? Does your opinion change because he put himself at risk?

5 **Investigate** one of the following common diseases:

- diabetes
- pneumonia
- coeliac disease
- osteoperosis.

For your chosen disease, answer the following questions.

a **Describe** the disease in your own words.

b **Identify** what body system(s) the disease affects.

c **Describe** the symptoms of the disease.

d **Outline** what treatment is currently available for the disease.

e **Discuss** how scientific discovery played a role in understanding and managing the disease.

Skills builder: Problem solving

6 Some health experts argue that cigarettes should be banned given the known health risks. **Evaluate** this solution in small groups before bringing your group's thoughts to a class discussion.
(THINK: Were there differing opinions? Could a consensus be reached?)

13.4 Advances in technology solve medical issues



Figure 1 Artificial limbs have developed to focus on different needs, such as comfort, movement, strength or cost.

In this topic you will learn that:

- technologies, such as artificial joints, limbs and organs, can be used to solve medical issues.

Science and technology go hand in hand. In fact, technology is defined as the application of scientific knowledge for practical purposes. As scientific knowledge improves, technology soon follows. Improvements in technology allow us to develop greater scientific knowledge and the cycle goes on.

Artificial limbs

The first evidence of an artificial limb (prosthetic) dates back to nearly 3000 years ago. It was a big toe made of wood and attached to the foot via string. Throughout history, each technology usually improves upon the previous one. In 1946, the suction sock for lower-limb amputees was developed and is still used today. This technology improves comfort significantly by reducing the contact pressure of the artificial limb on the patient's skin.



Figure 2 A bionic hand is a prosthetic that can help people to perform tasks that a human hand would normally carry out, such as tying shoelaces or carrying bags.

In the 1970s there was a focus on producing artificial limbs that focused on improving a patient's comfort rather than mirroring the movement of a natural limb. Current research is focused on producing stronger, lighter and cheaper limbs that integrate with the patient's own nervous system to allow for control of the limb – the bionic limb.

The technology behind prosthetics is continuing to improve with bionic hands and limbs. Recently, researchers developed a bionic hand that could pick up signals from a person's muscles, which it then converts into movement in the prosthetic. In 2019, a team of researchers in the United States developed a prototype for a bionic hand that could also sense and feel things.

Artificial joints

Artificial joints have developed as scientists have learnt more about the skeletal system. In the past, doctors would attempt to remove all or part of a damaged joint in order to avoid amputation. However, these surgeries would result in significant side effects for the patient, including pain and loss of movement.

In the 1940s, the first modern metallic hip replacements began. Prior to this, a patient could not be guaranteed that the replacement would last. In the 1960s, the first metal–ceramic hip joint was developed and is the basis of artificial joints used today. It consists of a metal stem topped with a ceramic ball that is inserted into the femur of the leg. Strong acrylic bone cement is used to set the joint, which can usually last for the patient's lifetime.

Current research is using robotics to assist in the implantation of artificial joints. This will provide a more precise fit of the joint and improve patient outcomes.

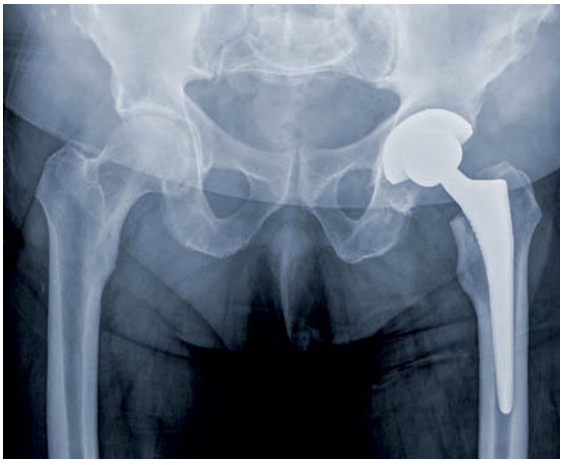


Figure 3 An X-ray of an artificial hip

Minimally invasive surgical techniques are now common practice to reduce damage to surrounding joint tissues, allowing for quicker patient recovery.

Artificial organs

Sometimes organs are unable to work as they should, leaving a person very sick or at risk of dying from organ failure. Organ transplants involve removing a working organ from a person who has recently died and putting it into a person whose organ has failed. But there is often a waiting list for organ donation because more people need new organs than there are people who donate them.

To solve this short supply, scientists are developing artificial organs to transplant into patients who need them. **Artificial organs** can include devices or tissues that either help an organ to function or replace it altogether. These artificial organs allow the person to continue living without waiting for a donor.

For example, a pacemaker monitors a person's heartbeat, delivering a painless electrical impulse to stimulate a heartbeat when needed. A pacemaker is a small battery-operated computer that is inserted during surgery and is connected to the heart (see Figure 4). It performs the same function as the sinus node (a group of cells in the heart) that is the heart's natural pacemaker. When the sinus node is damaged, an artificial pacemaker can help people with heart conditions to live longer and lead more active lives.

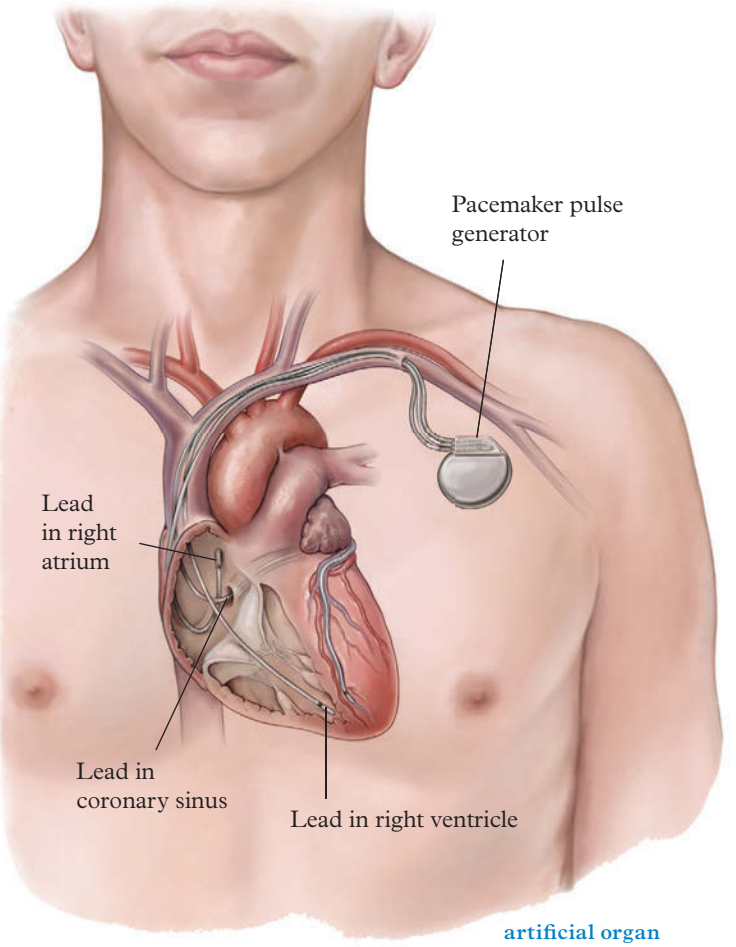


Figure 4 An artificial cardiac pacemaker

artificial organ
a device or tissue developed to replicate the function of a real organ

Check your learning 13.4

Recall and explain

1 **Describe** the relationship between health science and technology.

2 Use an example to **explain** the idea of an artificial organ.

Apply and analyse

3 **Recall** another health issue that was discussed earlier in this chapter (such as bowel cancer or coronary heart disease). How has technology helped to find a solution for treating these diseases?

Skills builder: Communicating

4 In small groups or independently, **investigate** how developments in technology have contributed to finding solutions to one of the following contemporary issues: organ transplantation, treatment for diabetes, asthma, kidney disease or a topic agreed on by your teacher.

Communicate your findings to the class as a short presentation, video, poster or audio clip.

(THINK: How will you engage your audience?)

13.5 People have different opinions about health issues

In this topic you will learn:

- how different groups of people value contemporary issues.

There is a range of factors that influence the value that different groups place on contemporary issues. People's views may be influenced by many things, including:

- scientific understanding
- religious, political or cultural beliefs
- worries about finances or money
- a sense of justice or fairness.

When forming your own opinion on what can be controversial issues, it is important to listen to as many points of view as possible and always discuss issues in a respectful manner. There may not be a right or wrong – just different points of view. In this topic, we will ask more questions than we answer.

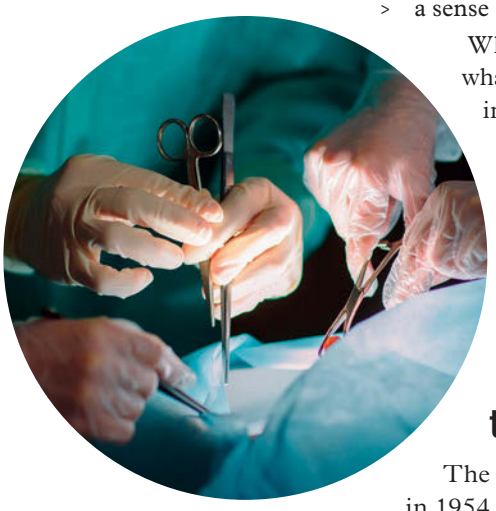


Figure 1 Organ transplants can save lives, but they can also be costly.



Figure 2 Should smoking be banned to keep people healthy, or should people continue to have the right to choose?

Are organ transplants ethical?

The first organ transplant occurred in 1954. It was a kidney. Liver, heart and pancreas transplants soon followed. By the early 2000s, full face transplants could be performed. Thousands of lives have been saved through these procedures.

It is estimated that organ transplants, such as lung, heart and liver transplants, each cost around $150 000. But who should pay for the surgery? Should it be covered by taxpayers or left to the patient to pay? What if patients can't afford to pay?

Some religions do not permit organ transplants. So some people may refuse organ transplants for themselves or their children because they do not believe these transplants are morally correct. Does the government or hospital have the right to intervene?

People also worry about where the organs are coming from. Do families have the right to donate a deceased person's organs? If someone is unlikely to recover from life support, does anyone have the right to take them off life support so that their organs can be harvested?

Each of these questions will have different answers depending on who you ask. What do you think of these ethical questions?

Should smokers receive free healthcare?

As we discussed in 13.3, studies in the 1950s linked smoking cigarettes to developing lung cancer. But even though most people know the risks of smoking, some people still choose to smoke. Some health advocates argue that cigarettes should simply be banned, while others believe in the freedom to choose.

If someone who chooses to smoke develops lung cancer, should the government have to pay for their health care? Doctors have a duty to care for all individuals, so who has the right to decide who gets help and who doesn't?

Should vaccines be compulsory?

Millions of lives are saved each year by vaccines. They prevent us from contracting diseases that once would have been fatal.

The world's first vaccine was developed in 1796 by English physician Edward Jenner (1749–1823). Jenner's methods, however, were questionable. He injected a young boy with cowpox virus – a related but weaker virus than the one that caused smallpox, which was highly contagious and deadly. The vaccine provided



Figure 3 Vaccinations have helped to eradicate a number of deadly diseases, such as smallpox.

the boy with protection from the smallpox virus. A systematic vaccination program subsequently led to the total eradication of smallpox from the planet.

Diseases that were once commonplace such as polio, cholera, measles and rubella are now avoidable due to vaccination.

But as death rates from fatal diseases dropped, some people began to question the value of vaccines.

Most people argue that specific vaccinations that protect society should be compulsory. This does, however, come at the expense of people's right to choose for themselves. Should parents or religious groups be allowed to choose whether their children are vaccinated? Should day-care centres and schools be allowed to prevent non-vaccinated children from attending?

Video
Vaccines

Who is responsible for our healthy diet?

Type I diabetes is a genetic disease that leads to the body being unable to produce insulin, which is the molecule that breaks down glucose (sugar) in the body. While type I diabetes can be treated, it cannot be prevented due to the genetic link. In contrast, type II diabetes can be caused by a combination of factors, such as poor diet, being overweight, smoking and excess alcohol intake. This leads to increased risk of other illnesses, such as heart disease and atherosclerosis.

Given it has links to our personal lifestyle choices, the treatment of type II diabetes raises some questions. Who should pay for the treatment? Should supermarkets play a more active role in promoting healthy food over junk food and drinks? Should sugary drinks be sold in schools?



Figure 4 Does the government have the right to stop people from eating foods that can cause type II diabetes?

Check your learning 13.5

Recall and explain

1 **Identify** two different points of view associated with organ transplantation.

2 **Identify** two different points of view associated with the control and prevention of lung cancer caused by smoking cigarettes.

3 **Identify** two different points of view associated with the control and prevention of type II diabetes.

Apply and analyse

4 **Explain** why different groups of people in society weigh criteria differently when making decisions about the application of solutions to organ transplantation, control and prevention of lung cancer caused by smoking cigarettes, and control and prevention of type II diabetes.

Evaluate and create

5 **Evaluate** the methodology used by Edward Jenner to develop the smallpox vaccine. Do you believe it was ethical to inject a young boy with the cowpox virus, without knowing what the consequences would be? Consider the millions of lives saved, however, as a result of his research.

6 **Discuss** how different groups of people in society use or weigh criteria differently in making decisions about the application of a solution to a disease or dietary deficiency.

Skills builder: Processing and analysing information

7 Select one of the ethical questions raised in this topic, such as about organ donation, free healthcare for smokers, vaccinations or compulsory health foods.

a **Identify** as many arguments *both* for and against the question as you can.

b **Construct** a table that organises all the arguments you identified (for and against) in the previous question.

c Using the information you have gathered for the table, what do you think is the answer to the question? **Justify** your answer.
(THINK: There may not be a correct answer to your question, so provide the reasons to explain why you have your opinion.)

REVIEW

Multiple choice

1 **Recall** which person is known for their scientific discovery on the importance of handwashing.
- **A** Howard Florey
- **B** Florence Nightingale
- **C** Ignaz Semmelweis
- **D** John Snow

2 A stent can be used to treat which of the following health issues?
- **A** Coronary heart disease
- **B** Diabetes
- **C** Stomach ulcers
- **D** Lung cancer

3 According to germ theory, what causes diseases?
- **A** Bad air
- **B** Eating too much sugar
- **C** Specific pathogens
- **D** Random generation

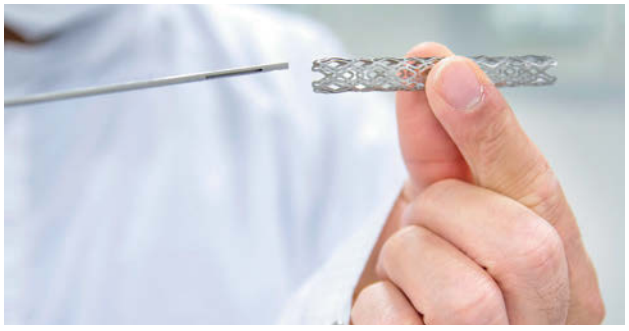


Figure 1 A medical stent

Recall and explain

4 **Describe** two hygiene practices that can stop us from getting sick.

5 **Recall** one example of an advance in scientific understanding that assisted in the prevention of infectious disease.

6 **Describe** the experiments performed by Howard Florey to show the effect of penicillin.

7 **Explain** why the discovery of germs was important for human health.

8 Artificial limbs are not a recent invention, but the technology behind them has improved.
- **a** **Describe** how advances in technology have improved artificial limbs. Explain why this improvement is so important.
- **b** **Identify** three different values that might influence someone's opinion on organ transplants.



Figure 2 Artificial limbs

Apply and analyse

9 **Distinguish** between miasma theory and the germ theory.

10 **Explain** the difference between preventing a disease and treating a disease.

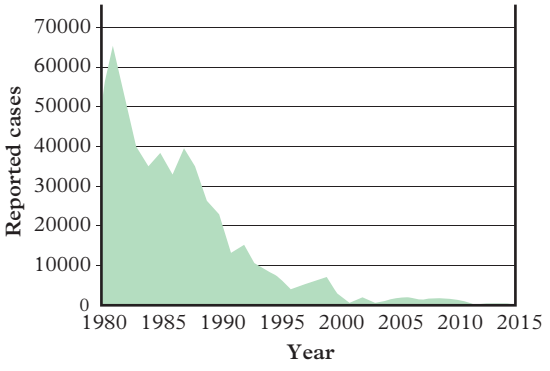
11 **Analyse** the table following, which shows the number of smokers in Australia from 2001 to 2014.

Table 1 Smokers in Australia, 2001 to 2014

Year	2001	2004	2007	2011	2014
Smokers (% of the population)	24.2	23.3	20.1	17.4	15.5

- **a** Plot this data as a graph. (Remember to label the *x*- and *y*-axes and to give your graph a title.)
- **b** **Describe** any trends you can see in the number of smokers in Australia over time.
- **c** **Propose** a reason to explain this trend.

12 Polio is a highly infectious disease that mainly infects children under the age of five. It can lead to paralysis and in some cases death. In 1988, many governments and health organisations around the world united to form the Global Polio Eradication Initiative. The goal was to prevent the spread of the disease through immunisation. Using this information and Figure 3, answer the following questions.



Source: World Health Organization

Figure 3 Reported cases of polio, 1980 to 2017

- **a** **Examine** Figure 3 shows the number of polio cases worldwide from 1980 to 2017. **Describe** the trend you see.

b **Propose** a reason for why the reported polio cases might have gone up between 1980 and 1988.

c Use the data in Figure 3 to **assess** the impact of the Global Polio Eradication Initiative.

Evaluate and create

13 **Discuss** the role that science and technology play in human health.

14 **Assess** the importance of Edward Jenner's work on vaccines.

15 **Evaluate** the idea that the sale of cigarettes should be banned.



Figure 4 The no smoking sign

16 **Construct** a poster that communicates the benefits of scientific research to a real-world problem.

17 **Discuss** the importance of scientific education for better hygiene practices. Is it important to know why you need to wash your hands?

18 COVID-19 is an infectious disease caused by a type of virus called a coronavirus. Beginning in late 2019, the spread of COVID-19 became a global pandemic. **Describe** two or three hygiene practices that became important to prevent the spread of COVID-19 in the community. Do you think it is important for people to understand the science behind these hygiene practices? **Discuss**.

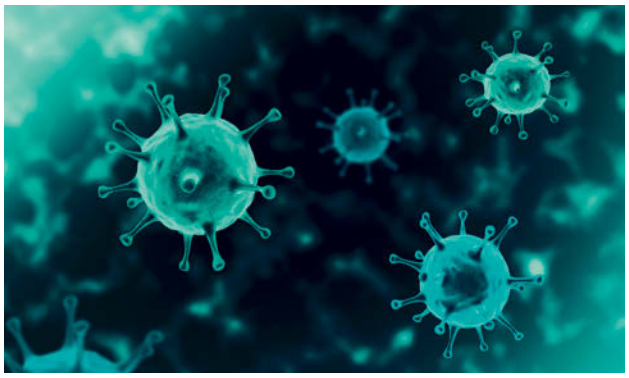


Figure 5 A three-dimensional rendering of the COVID-19 virus

Critical thinking

19 Should the government pay for biological research? Using what you have learnt in this chapter about advances in science and technology to treat and prevent disease, formulate an argument for or against. You should also develop a rebuttal for potential counter arguments.

20 Should fast food companies be allowed to advertise junk food at sporting events such as NRL games or the Olympics? What kind of values would influence your opinion? **Construct** a table that outlines arguments for and against advertising junk food at sporting events, and include a column that identifies the kind of values (e.g. health, money) that might influence each opinion.



Figure 6 Should advertising for junk food be allowed at sporting events?

Going further

21 Organ transplants are often trialled first on animals to make sure they are safe for humans. **Evaluate** the ethics of this practice. What are the advantages and disadvantages?

22 Are people in developing countries without access to running water at a greater health risk than people living in developed cities? **Justify** your reasoning.

Research

23 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

»Spray-on skin

Australian scientist Fiona Wood developed spray-on-skin technology to help treat burn victims. How does spray-on skin work? What problem was Wood trying to solve?

»Sewage treatment

Since John Snow discovered the link between contaminated drinking water and cholera, scientists have understood the importance of sewage treatment. But how does sewage treatment work today? **Investigate** the wastewater treatment plants in New South Wales. How do they make sure we have clean drinking water?

»Potato blight

In the 1800s, Ireland experienced what is now called the Great Famine. During the famine, a potato blight infected and destroyed potato crops, leaving the population in extreme poverty and facing starvation. During this period, more than one million people died. **Investigate** the potato blight. How did it spread? How could this plant disease have been prevented?



Figure 7 Potatoes with blight

Reflect

Now that you've completed this chapter, reflect on your ability to do the following:

	I can do this.	I can't do this yet.
Research an example of how changes in scientific knowledge have contributed to finding a solution to a human health issue.	☐	☐ Go to page 228–235.
Recount how evidence from a scientific discovery has changed understanding and contributed to solving a real-world problem, e.g. animal or plant disease, hygiene, food preservation, sewage treatment or biotechnology.	☐	☐ Go to page 228–235.
Describe, using examples, how developments in technology have contributed to finding solutions to a contemporary issue, e.g. organ transplantation, artificial joints/limbs, treatment for diabetes, asthma, kidney or heart disease.	☐	☐ Go to page 236–237.
Give examples to show that groups of people in society may use or weight criteria differently in making decisions about the application of a solution to a contemporary issue, e.g. organ transplantation, control and prevention of diseases and dietary deficiencies.	☐	☐ Go to page 238–239.

Source: NSW Science Years 7–10 Syllabus © NSW Education Standards Authority for and on behalf of the Crown in right of the State of New South Wales, 2018.

ECOSYSTEMS

How does science help to manage ecosystems?

Have you ever wondered ...

- Can the human population continue to grow?
- Why are there fewer carnivores than herbivores?
- Is cloning good or bad?

14

SCIENCE UNDERSTANDING

In this chapter you will learn how to:

- construct and interpret food chains and food webs, including examples from Australian ecosystems
- describe interactions between organisms in food chains and food webs, including producers, consumers and decomposers
- describe examples of beneficial and harmful effects that micro-organisms can have on living things and the environment
- predict how human activities can affect interactions in food chains and food webs, including examples from Australian land or marine ecosystems
- explain, using examples, how scientific evidence and/or technological developments contribute to developing solutions to manage the impact of natural events on Australian ecosystems
- describe how scientific knowledge has influenced the development of practices in agriculture, e.g. animal husbandry or crop cultivation to improve yields and sustainability, or the effect of plant-cloning techniques in horticulture.

Source: NSW Science Years 7–10 Syllabus © NSW Education Standards Authority for and on behalf of the Crown in right of the State of New South Wales, 2018.

Check your Student obook assess for these digital resources and more:

QuizletLive
Compete in teams to test your knowledge.

Assess quiz
Before you start this chapter, assess your science skills.

Check your Teacher obook assess for these digital resources and more:

QuizletLive
Launch a quiz for your students on key concepts in this chapter.

14.1 An ecosystem is a community of living organisms

In this topic you will learn that:

- an ecosystem is made up of biotic and abiotic factors.

Living organisms can be found almost everywhere on Earth, but they do not live in isolation. Organisms interact with individuals of their own species and with other species, including humans. Though extremely diverse and well adapted to suit their particular ecosystems, all organisms have one thing in common – the need for energy. Where does this energy come from, and how does it move through ecosystems?

The biosphere

biosphere
the regions of the lithosphere, hydrosphere and atmosphere inhabited by living organisms

The **biosphere** describes our living world. It is where all of the plants, insects and animals live. The biosphere extends to any place that life, of any kind, can exist on the Earth. The biosphere can be thought of as the intersection between the atmosphere (gases), the hydrosphere (water) and the lithosphere (land). Since the biosphere is large and all-encompassing and its relationships are so complex, we normally study smaller components of the biosphere. These smaller components are called ecosystems.

Ecosystems

biotic
all the living organisms in an ecosystem

abiotic
all the non-living components of an ecosystem; for example, light, temperature and water

ecosystem
a number of communities together with the surrounding non-living factors

habitat
an environment in which an organism lives

Ecosystems vary in size. They can be as small as a puddle or as large as the ocean. Any group of **biotic** (living) and **abiotic** (non-living) things interacting with each other in a self-sustaining way is an **ecosystem**. Ecosystems are made up of habitats. A **habitat** is the place where a population of organisms live. Habitats vary in size depending on the amount of food, water and shelter they provide. For example, in Kakadu (see Figure 1a), habitats include billabongs, rivers and floodplains.



Figure 1 Australian ecosystem examples: **a** Kakadu National Park wetlands; **b** Daintree Rainforest; **c** The Great Barrier Reef

CHALLENGE

14.1: Making a biosphere
Go to your obook.



Figure 2 a A colony of emperor penguins forms a population. **b** Penguins interact with fur seals as part of a community.

A **population** is a group of living organisms from the same species, living in the same place at the same time. When populations of different species interact with one another, they are called a **community**. For example, a population of humans can live in a town together. When all the plants in their gardens and their pets are included, it becomes a community.

The habitat must supply all the needs of the organisms, such as food, water, oxygen and minerals. These make up the abiotic conditions of the habitat. If the abiotic conditions are not appropriate for a population, it will move to a better habitat or will die out.

Benefits of an ecosystem

Humans are dependent on ecosystems for survival. Ecosystems provide a number of benefits to ensure our continued existence.

Plants and animals constantly cycle gases among themselves, the soil and the air. For example, during the day, plants take in carbon dioxide from the air and release oxygen into the air during a process called photosynthesis. Animals, including humans, use oxygen in cellular respiration and release carbon dioxide into the air. (The processes of photosynthesis and respiration are examined in chapter 12.)

population
all the inhabitants of a particular habitiat

community
different populations living in the same place at the same time

Check your learning 14.1

Recall and explain

1 **Recall** which three spheres interact to form a biosphere.
2 **Recall** the scientific word for non-living components of an ecosystem.
3 **Identify** an example of a habitat.

Apply and analyse

4 **Distinguish** between an ecosystem, habitat, population and community. Give an example of each.
5 **Assess** the importance of ecosystems for human survival.

Skills builder: Communicating

6 Imagine that someone walked up to you and asked the following question: 'Why is the environment so important?' Draft a reply, taking into account the key concepts covered here. (THINK: What are the key points that someone would need to know to be convinced?)

14.2 Energy flows within an ecosystem

In this topic you will learn that:

- a food chain shows the linear feeding relationship (energy flow) between a group or organisms
- a food web is more complex than a food chain, showing multiple feeding relationships (energy flows) within an ecosystem.

autotroph
an organism that makes its own 'food', such as glucose, through photosynthesis

heterotroph
an organism that consumes other organisms to obtain energy

The main source of energy on Earth is sunlight. As we learnt in chapter 12, plants can obtain all the energy they need by converting sunlight into useable energy through photosynthesis. This makes them **autotrophs** (*auto* meaning 'self' and *troph* meaning 'nutrition'). Organisms who need to eat food to obtain energy, such as humans, are called **heterotrophs**.

Knowing who eats whom can be very useful information, particularly when looking at how people have an impact on the natural environment. Scientists use a food chain to show the flow of energy in an ecosystem.

Food chains

A food chain shows a list of organisms in the order of what eats what with an arrow between each organism to indicate the direction of energy flow.

A food chain always starts with a producer organism followed by a first-order consumer (primary consumer) followed by a second-order consumer (secondary consumer) and so on (see Figure 1).

A food chain always points towards the animal doing the eating. For example, a centipede eats a wolf spider (see Figure 2).

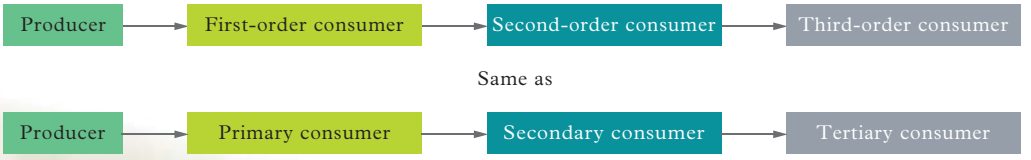


Figure 1 A food chain starts with producers and moves through several orders of consumer.

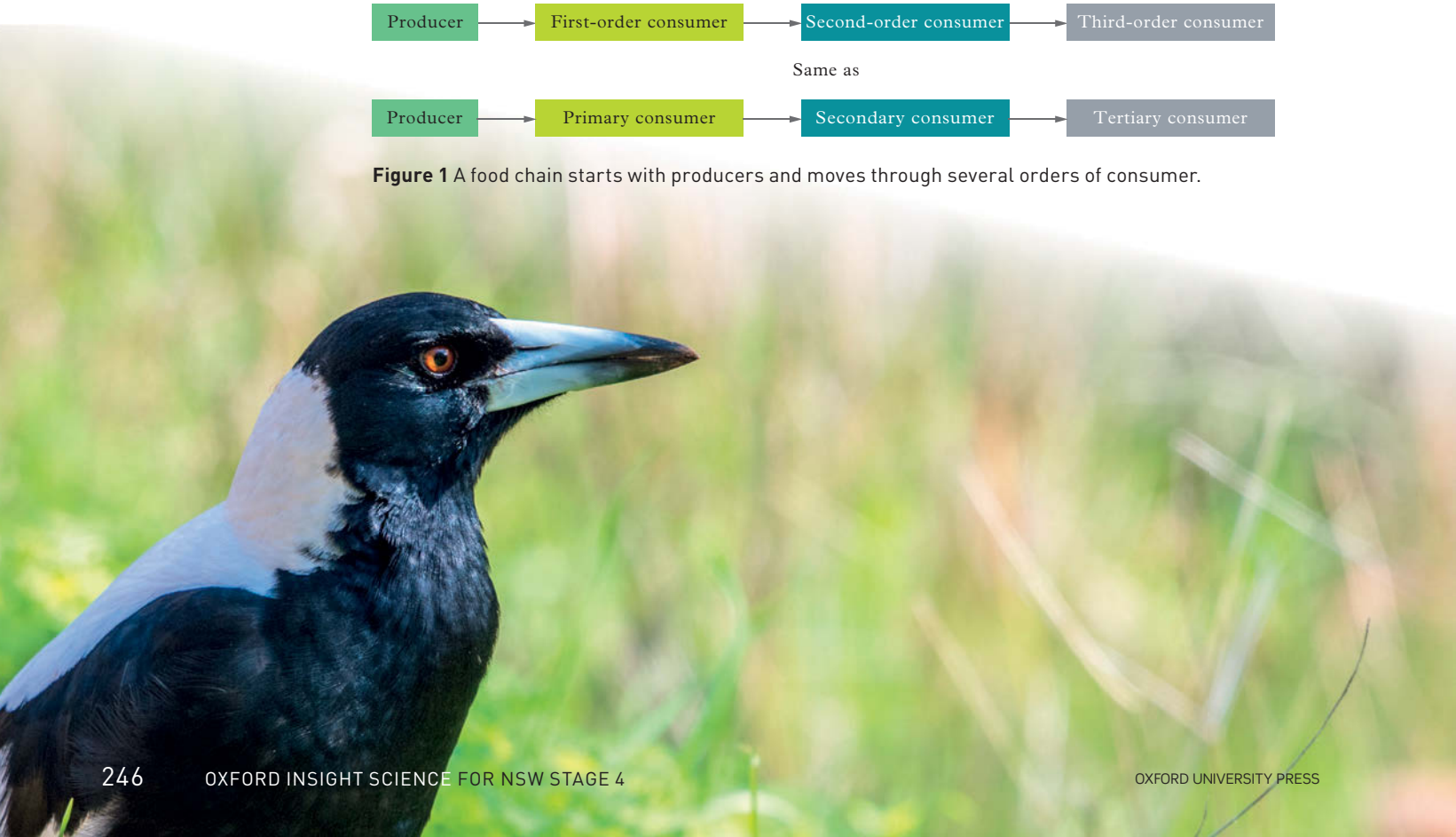




Figure 2 A simple food chain

This means the arrow points from the wolf spider to the centipede. These arrows show the movement of energy (food) in the system. The wolf spider provides the centipede with energy to grow and move.

Autotrophs are always found at the start of food chains because they only need air, water, sunlight and a few trace minerals to live and grow. These organisms are also known as the **producers** of the ecosystem because they produce their own 'food'. They convert light energy from the Sun into sugars (stored chemical energy).

Heterotrophs are called **consumers** because they must consume other organisms to get the energy they need in order to survive. They then use this energy to stay alive – to pump their blood, to move their muscles and to operate their nerves. The first consumers in a food chain are also referred to as first-order (or primary) consumers.

Most food chains only have four to five organisms in them. This is because only some of the energy is passed between organisms. At each level, energy is lost to the environment as the organism performs life functions (Remember: MR N GREWW).

In Figure 3 a grasshopper eats grass. The grass is the producer and the grasshopper is therefore a first-order consumer. Because the butcher bird eats a first-order consumer, it is called a second-order consumer. The eagle eats the butcher bird and becomes a third-order consumer. When the eagle dies its body is broken down by **detritivores** and decomposers. The arrow points from the grass to the grasshopper to show the movement of energy (food) in the system.

Interactive
Food chains

detritivore
an organism that obtains nutrients by consuming detritus (decomposing plant and animal parts)

Food webs

Like humans, most animals will eat more than one type of food. This can be represented in a **food web**, which shows several food chains intertwined. Some consumers will have several labels depending on their eating habits. Figure 4 shows a food web in which there are four different producers. The sparrow can be considered a primary and secondary consumer, whereas the snail is a primary consumer only.

Food webs show how each organism in the environment is dependent on the others for their survival. When people talk about the 'web of life', they are referring to the interactions between all living things.

Food webs show how all organisms within an ecosystem are dependent on one another, even if they do not share a direct feeding relationship. For example, if the spider was removed from the food web in Figure 4, it may impact on the number of beetles and butcher birds. Can you figure out why?

producer
a plant or plant-like organism found at the start of food chains

food web
several intertwined food chains, showing the extended relationships between different organisms

consumer
an animal that cannot convert the Sun's energy into sugars and must eat to get the energy they need to survive

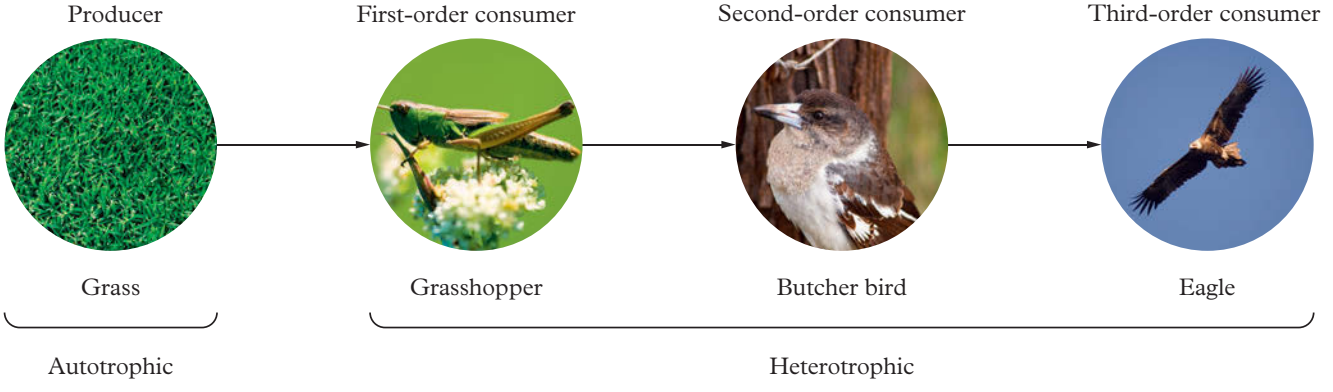


Figure 3 An example of a backyard food chain

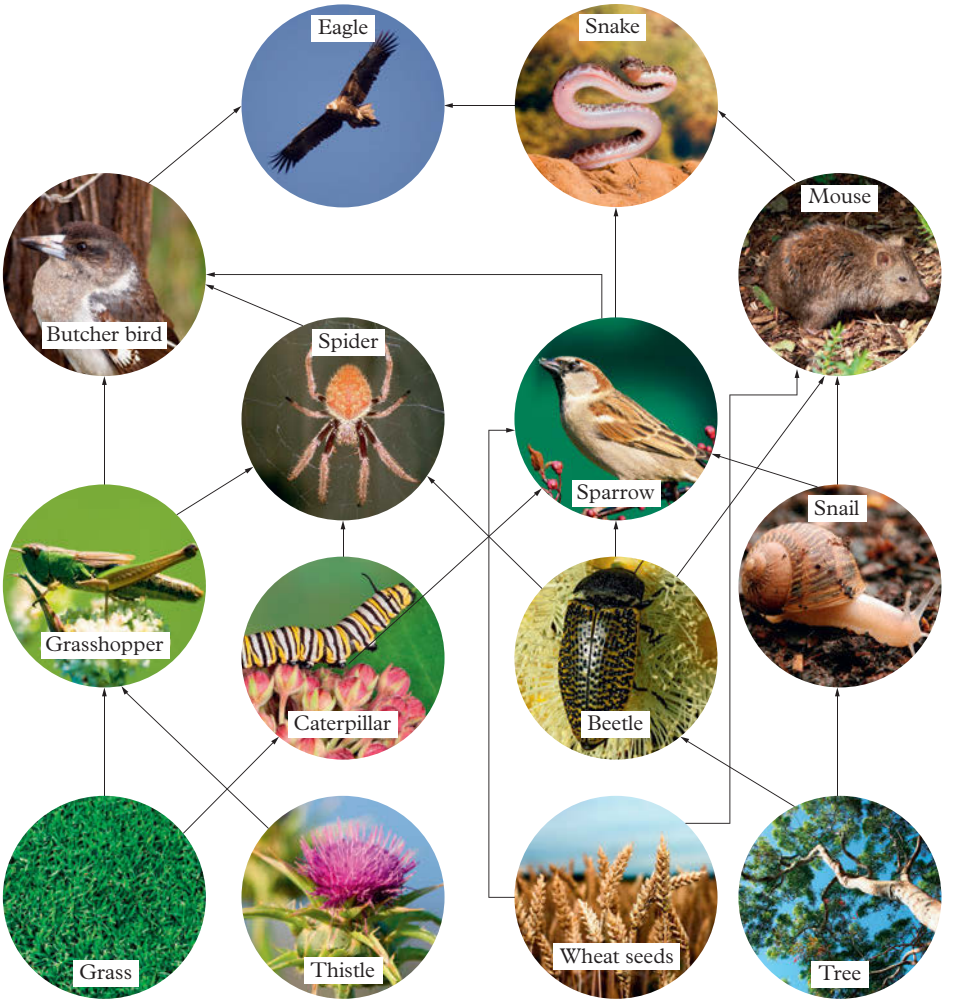


Figure 4 A food web shows the extended relationships between various organisms.

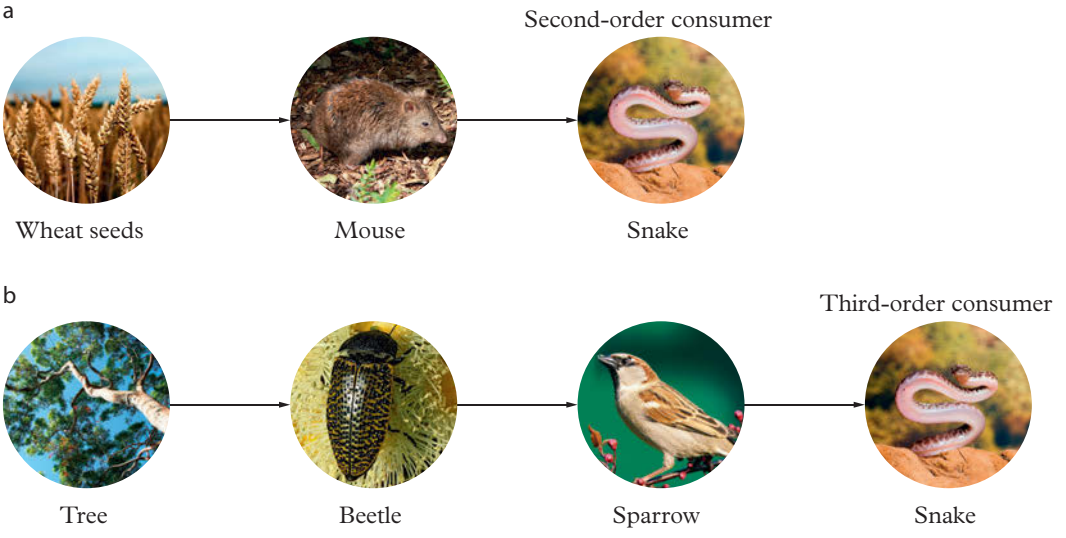


Figure 5 a A food chain from the food web in Figure 4, showing the snake as a second-order consumer, and **b** the snake as a third-order consumer

Case study: Dorrigo National Park

Dorrigo National Park is located in north-eastern New South Wales and is filled with different forest environments. Energy flows through the national park from producers to consumers as part of an ecosystem.

Dorrigo National Park has many species of eucalypt trees, such as the Dorrigo white gum. Coachwood trees also grow well there, producing white flowers and red fruits in spring and summer that king parrots can feed on. Brush turkeys living in the park feed on fallen fruit, along with insects and seeds they find in the leaf litter.

Common ringtail possums live in the national park and are mainly active at night. The possums use their powerful claws to search trees, foraging for gum leaves, flowers and fruits.

Spotted-tail quolls are also found in the national park. They hunt mostly at night and are known to eat small mammals such as possums, and even some small reptiles and birds. The quolls are threatened by foxes. Foxes can hunt spotted-tail quolls for food, but they also hunt for smaller animals like possums, reptiles and birds.



Figure 8 a spotted-tail quoll; **b** A common ringtail possum



Figure 6 Dorrigo National Park is home to many plant and animal species that interact.

Check your learning 14.2

Recall and explain

1 If food chains start with plants, **identify** where plants get their energy from.

2 **Explain** the difference between food chains and food webs.

3 **Explain** what the arrows in a food chain represent.

Apply and analyse

4 **Examine** the food web in Figure 4.

- a **Identify** an animal that is both a secondary and a tertiary consumer.
- b **Classify** the eagle as a type of consumer or producer.
- c **Predict** how the food web would be affected if humans had not introduced cats into this Australian ecosystem.

5 **Analyse** the food chain shown in Figure 9 and identify corrections that need to be made.

6 Read the case study on Dorrigo National Park.

- a **Identify** two consumers and two producers in Dorrigo National Park.
- b **Construct** a food chain that shows a producer, a first-order consumer and a second-order consumer in the park.
- c **Construct** a food web for the park that includes at least six organisms.

Evaluate and create

7 **Construct** an Australian food chain from producer to third-order consumer. For a challenge, include five or six trophic levels.



Figure 9 A food chain

Skills builder: Planning investigations

8 A group of students was asked to go outside of the classroom to observe a food chain in action.

- a **Identify** a location they could use to observe a food chain. (THINK: Where would they likely see a food chain in action?)
- b What equipment should they take with them? (THINK: What will they need to record their observations?)

14.3 All organisms are interdependent

herbivore
an animal that eats only plants

carnivore
an animal that eats only meat

omnivore
an animal that eats both plants and animals

decomposer
organisms, such as bacteria, that break down on dead organisms

In this topic you will learn that:

- organisms in an ecosystem rely on one another for survival.

All food chains start with a producer organism. The term 'producer' indicates they produce their own food (glucose) through the process of photosynthesis. Producer organisms are eaten by a first-order consumer, which in turn is eaten by second-order consumers and so on.

But there are other terms that we can use to describe the relationships between organisms and where they sit in food webs.

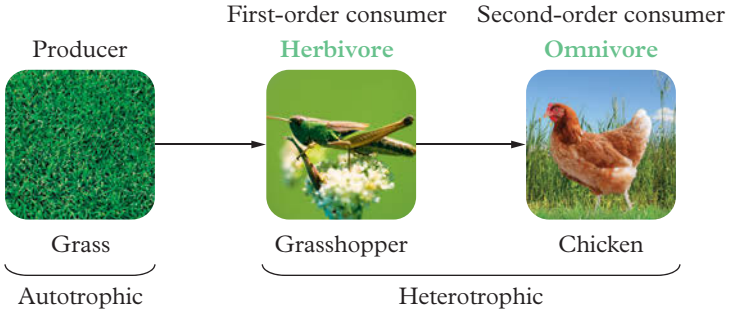


Figure 1 A food chain highlighting the different terminologies used



Figure 2 Decomposers recycle important nutrients and energy in an ecosystem.

Herbivores, omnivores and carnivores

Consumers are also named according to what they eat. First-order consumers that *only* eat producers (plants) are called **herbivores**. Organisms that *only* eat other consumers are called **carnivores**. Consumers that eat both plants and other animals, like many humans do, are called **omnivores**. The highest carnivore in a food chain is referred to as the apex predator.

Decomposers

Locked inside all organisms is an enormous amount of nutrients and energy. All organisms in a food web eventually end up passing these nutrients and energy on to decomposers. **Decomposers**, such as bacteria, fungi and some invertebrates (for example, slugs and worms), obtain the food they need by feeding on dead organisms. Decomposers such as fungi and bacteria do not eat dead matter – they break it down externally through chemical processes (see Figure 2). Other decomposers, known as detritivores, actually consume dead and decaying matter and excrete nutrients. Worms, maggots, and termites are classified as detritivores because they feed through oral digestion.

Decomposers prevent dead organisms from piling up. Instead, the nutrients stored in the dead organisms are used for energy by the decomposers. When another organism eats a decomposer, the nutrients once again become part of the food chain. The nutrients that pass through the decomposers as waste end up in the soil in simpler forms. Plants roots can then absorb the nutrients and the cycle starts again.

CHALLENGE
14.3: Exploring leaf litter
Go to page **391**.

INVESTIGATION
14.3: What if water was filtered through a pot with native grasses?
Go to page **391**.





Figure 3 a Mushrooms (fungi) are decomposers. **b** Termites are detritivores.





Figure 4 a Worker green weaver ants building a nest and **b** protecting the tree from invading caterpillars

symbiosis
a ongoing close relationship between two organisms; mutualism, commensalism or parasitism

mutualism
a symbiotic relationship in which both organisms benefit

Figure 5 This honeyeater (*Meliphaga gracilis*) feeds on the grevillea and, in doing so, helps the plant to pollinate.



Symbiosis

Sometimes, organisms from different species develop an ongoing relationship for their survival. When this happens, it is called **symbiosis**. Types of symbiosis include mutualism, commensalism and parasitism.

Mutualism

Mutualism is the word we use to describe relationships between species that are *mutually* beneficial. For example, green weaver ants (Oecophylla *smaragdina*), found in northern Australia, build their nests by weaving together the leaves of the tree (see Figure 4). The tree will also provide nourishment in the form of sap to support the ant colony. In return, the ants will aggressively defend the tree from other would-be pests. They do this by biting them and squirting acid into the wound. So this relationship benefits both the ants and the tree.

Pollination is another example of mutualism. Over 70% of plants are pollinated by animals. Australian honeyeaters (see Figure 5), fruit bats and native stingless bees obtain their food (pollen and nectar) from plants such as eucalypts and grevillea. In return, the animals transfer pollen between plants, which helps them to pollinate and reproduce.



Figure 6 Two cattle egrets (*Bubulcus ibis*) looking for insects on the back of a water buffalo.

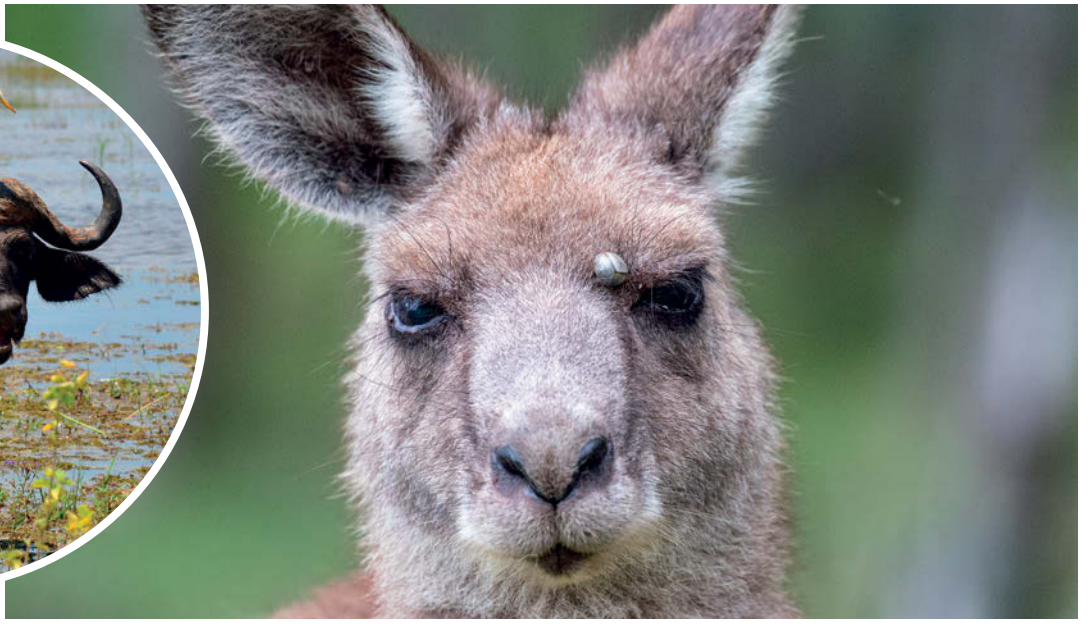


Figure 7 A large tick feeds on blood above the eye of an eastern grey kangaroo.

commensalism
relationship between two organisms from different species, in which one organism benefits and the other organism is not affected

predator
an organism that kills and eats other animals (prey)

prey
an organism that is killed and eaten by a predator

parasitism
a symbiotic relationship in which one organism (parasite) benefits and the other (host) is harmed but not usually killed

Commensalism

Commensalism describes a relationship between organisms in which one organism benefits and the other is unaffected. For example, a type of bird called an egret is often found sitting on the back of a buffalo or other types of cattle. As the buffalo grazes, it stirs up insects, which the egret can then find and eat. The buffalo does not gain anything from this relationship, but the egret causes no harm.

Parasitism

Parasitism is a relationship in which one organism (the parasite) benefits while the other organism (the host) is harmed. For example, ticks are parasites that attach to animals as they move through their habitat. The ticks benefit by taking a blood meal from their hosts. The hosts are harmed due to the loss of blood and the possible spread of disease.

Predator and prey

Carnivores and omnivores need to get their meat from somewhere. In a predator–prey relationship, one organism (the **predator**) kills the other (the **prey**) for food. Unlike the different symbiotic relationships, the predator–prey relationship is not ongoing. Examples of predators include the wedge-tailed eagle and the great white shark (Figure 8)

Carnivores can also consume animals that have already died. These scavengers feed off decaying animal material called carrion. For example, the Australian sheep blowfly will consume carrion as well as decaying fruit.

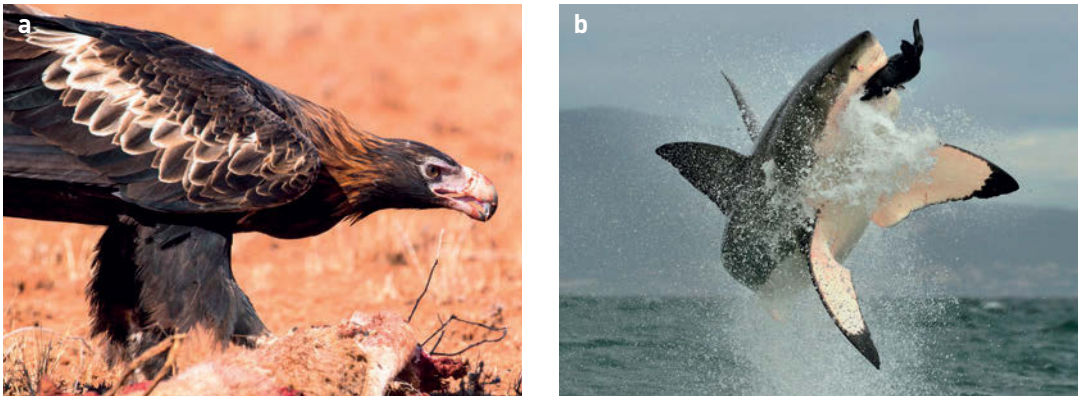


Figure 8 a A wedge-tailed eagle feeds on a kangaroo. **b** A great white shark hunts a seal.

Scavengers might eat organisms that have died of natural causes or organisms that have been killed by another predator.

Competition between organisms

Sometimes, organisms must compete for the same resources. What you may not realise is that most competition comes from members of the same species. This type of competition is called intraspecific competition. The reason for this is that members of the same species usually want the same food, water, shelter or mate. In contrast, interspecific competition occurs between members of different species. For example, a kangaroo and wombat may compete for the same grasses to eat.



Figure 9 a Intraspecific competition: a group of koalas; **b** interspecific competition: a wombat and an eastern grey kangaroo.

Check your learning 14.3

Recall and explain

1 **Recall** what it means to be a herbivore, omnivore and carnivore. Provide examples of each.
2 **Distinguish** between a detritivore and a decomposer. Provide examples of each.
3 **Define** what is meant by the term 'symbiosis'. Give an example.
4 **Explain** what a detritivore is. How is it different from other decomposers.

Analyse and apply

5 Figure 10 shows a shoal of clownfish living in a sea anemone. The clownfish clean algae from the sea anemone, which in turn provides protection to the fish via their poisonous tentacles. **Identify** what type of relationship this is.

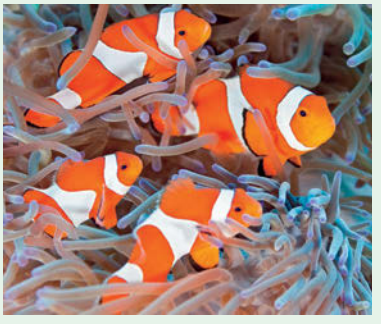


Figure 10 Clown fish

6 **Predict** one of the consequences if decomposers didn't exist.
7 **Distinguish** between predators and parasites.

Evaluate and create

8 There is growing concern about the falling number of bee species across the world because of loss of habitat and disease. **Assess** the possible consequences if all bees died.
9 Design an organism for a food web. What role does your organism play in the food web? What factors would affect the survival of your organism?

Skills builder: Communicating

10 **Construct** a table that summarises the differences between the different symbiotic relationships, including examples of each. (THINK: How can this table help people to understand these relationships?)

14.4 Micro-organisms can benefit other living things

In this topic you will learn that:

- micro-organisms are organisms that can only be seen with a microscope
- micro-organisms can be beneficial to other organisms and the environment.

Micro-organisms can only be seen with a microscope. They vary in size from one-tenth of a millimetre to one-thousandth of a millimetre. While they are represented by species from each kingdom, the significant majority are bacteria protozoa, and some fungi.

Micro-organisms can be found almost everywhere. They are in and on our bodies, and in our food and the soil.

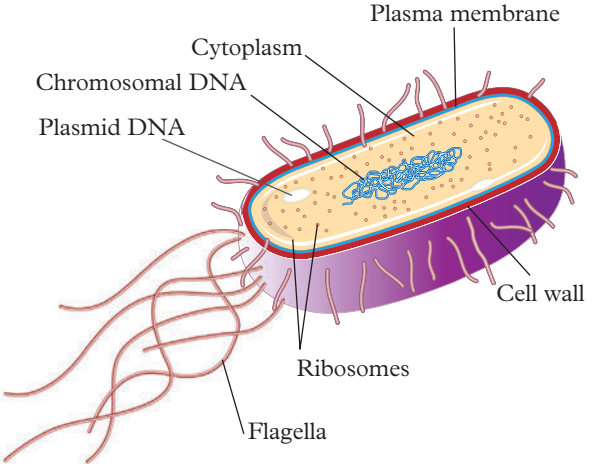


Figure 1 A bacterium cell

There are three main types of micro-organisms (also explored in chapters 10–11):

- bacteria – prokaryotic organisms that have DNA but no membrane-bound organelles
- protozoa – eukaryotic organisms usually much bigger than bacteria; some may have flagella or cilia to help them move around
- fungi – eurkaryotic organisms that can also be unicellular; they grow on surfaces, so they do not move around.

Some forms of bacteria are classed as extremophiles because they survive extremely harsh environments. For example, some bacteria can survive in volcanically heated springs at up to 90°C, while others can survive extreme toxicity and acidity.

Benefits of micro-organisms

Micro-organisms often have a reputation as things that can harm us. But in reality, we rely on micro-organisms for our survival, as do many other organisms and the environment. Table 1 outlines a small number of the benefits that micro-organisms can have.

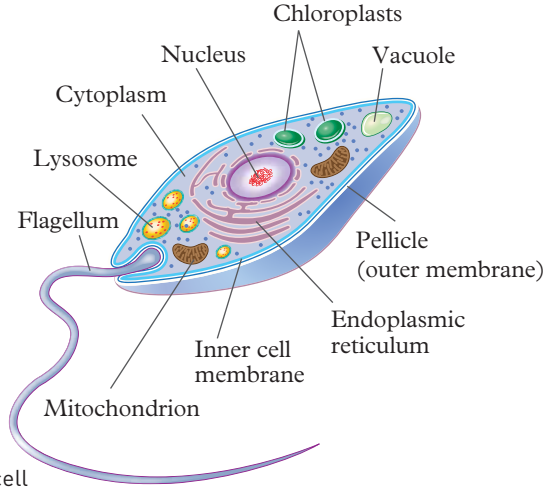


Figure 2 A protozoan cell

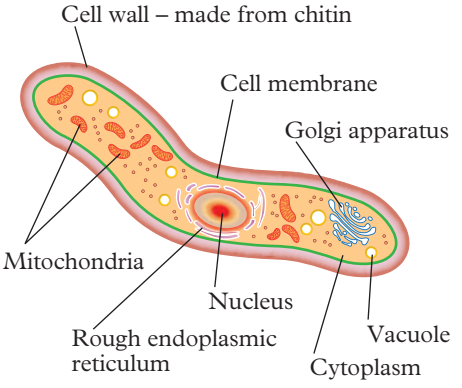


Figure 3 A fungal cell

Table 1 Benefits of micro-organisms

Benefit	Description	
Micro-organisms help plants to obtain nitrogen.	Plants need nitrogen to make many important molecules, including chlorophyll for photosynthesis. But sometimes there is not enough nitrogen in the soil. In these cases, plants can work with nitrogen-fixing bacteria in the soil. These bacteria take nitrogen out of the air and soil and transform it into a useable form for the plants. When the plant dies, the bacteria return to the soil for other plants to use.	 **Figure 4** Root nodules contain nitrogen-fixing bacteria.
Micro-organisms act as decomposers.	Decomposers include micro-organisms such as bacteria and fungi, which break down organic matter, helping nutrients to re-enter the food chain.	 **Figure 5** Mould (a fungus) is a decomposer.
Micro-organisms in our gut help us to digest food.	Our gut contains trillions of different bacteria that help us to digest food and manufacture vitamins. This is called the gut microbiota. The different bacteria in our digestive system are maintained by the food we eat, so a balanced diet is essential for all bacteria to function. We have other microbiota all over our body, including the skin microbiota and oral microbiota.	 **Figure 6** The gut microbiota is made up of trillions of bacteria.
Micro-organisms can be used to make foods.	Bacteria can be added to food to make fermented food products. For example, if you add a specific bacteria (e.g. *Lactobacillus delbrueckii*) to milk, you can make yoghurt. If you add bacteria to tea, you can make kombucha. Yeast is another micro-organism that is used to make bread rise.	 **Figure 7** Food such is yoghurt is made with bacteria.
Micro-organisms can be used to make biofuels.	Scientists have discovered a number of ways to make biofuels to power cars with plants instead of fossil fuels. One method is by using the bacteria found in panda faeces (poo) to help speed up the breakdown of a super-tough plant material known as lignocellulose. This allows scientists to make biofuels faster.	 **Figure 8** Bacteria found in panda poo is being used to speed up the process of making biofuels.

Check your learning 14.4

Recall and explain

1 **Define** the term 'micro-organism'.

2 **Recall** two ways that micro-organisms help us to survive.

Analyse and apply

3 An unknown micro-organism is viewed under a microscope. Each cell can be seen to have a cell wall and a cell membrane, to contain a nucleus and mitochondria, and to have flagella on the surface of the cell. **Classify** the group of micro-organisms these cells come from.

Evaluate and create

4 **Construct** a table or mind map to **compare** the three main groups of micro-organisms.

Skills builder: Problem solving

5 One of your classmates says that bacteria are 'all gross and dangerous'. **Evaluate** this claim and write a response to support or disagree with it. (THINK: What do you understand about micro-organisms? Use examples to support or reject this claim.)

14.5 Some micro-organisms cause harm

In this topic you will learn that:

- micro-organisms can cause harm to other organisms and the environment, as pathogens, or when they reproduce too quickly.

urbanisation
the process of making an area more urban

Most micro-organisms have a function that is beneficial to us or the environment. But a very small number of them can cause harm to other organisms.

Some of the world's biggest killers, including malaria and tuberculosis, are caused by micro-organisms. Agricultural industries can be shut down with the arrival of new micro-organisms that cause disease in animals and plant crops. They can also have negative effects on the environment.

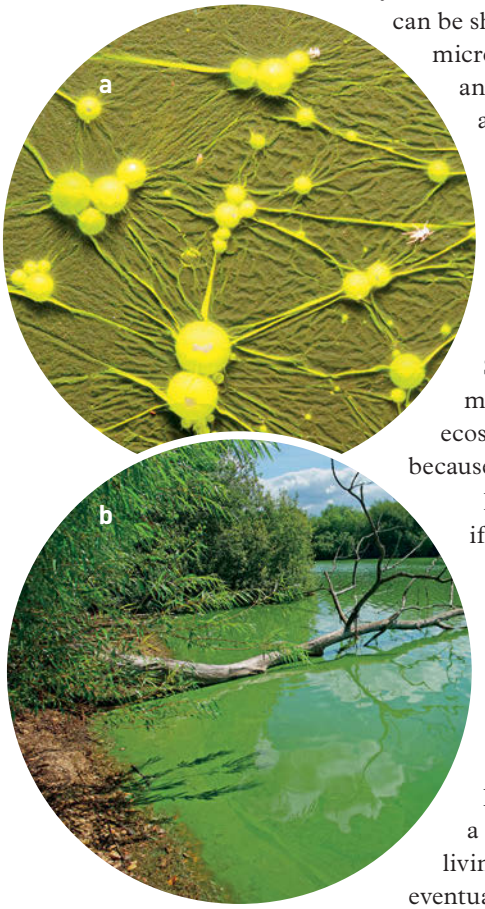


Figure 1 a Cyanobacteria; **b** cyanobacteria outbreaks cause algal blooms, which are harmful to other organisms in the ecosystem.

Too many micro-organisms can be damaging

Sometimes there can be too many micro-organisms present in an ecosystem. This can cause a problem because it throws off the balance.

For example, in aquatic ecosystems, if there are a lot of nutrients available in the water, algae and cyanobacteria in the water will reproduce more rapidly. This rapid increase in the population of algae or cyanobacteria is called an algal bloom. Algal blooms can turn the water green, yellow or red. But as more algae grow, it becomes a problem for the other organisms living in the ecosystem. When the algae eventually die, they use up the oxygen as they decompose. With less oxygen in the water, many fish and aquatic species cannot survive. If the algal bloom covers the surface of the water completely, it also blocks sunlight that aquatic plants require for photosynthesis.

Algal blooms can be caused naturally by changes in temperature or rainfall. But they are also caused by human activity. Agriculture and **urbanisation** play a role in developing algal blooms in nearby waterways. For example, fertiliser, sewage or city stormwater can flow into waterways and impact nutrient levels.

Pathogens can cause infectious diseases

A pathogen is a microbe that can cause an infectious disease. This means the disease can be spread by one organism passing the pathogen on to another organism. An infectious disease can make an organism sick or, worse, it may even be fatal. A pathogen can be considered a parasite because it lives off its host and can cause the host to become ill or die.

Pathogens can be bacteria, fungi or protists. Viruses and prions (rings of faulty proteins) can also cause diseases, but they are not considered micro-organisms because they are not living.

Pathogenic bacteria

To a lot of people, the word 'bacteria' means something dangerous or unhygienic. But, in fact, less than 1% of bacteria are considered harmful.

Depending on the species, bacterial pathogens can attach to host cells and harm them in a number of ways, including using the host's nutrients or producing toxic waste that damages the host. Table 1 includes examples of common bacterial pathogens.

Bacterial pathogens can be treated with antibiotics. But preventing a bacterial infection is a better strategy. Cuts and injuries can be disinfected to prevent bacteria entering a wound. When cooking, bacteria can be killed if the food is cooked to a high enough temperature. Some bacterial infections, like tetanus, can be prevented with vaccinations.

Pathogenic fungi

Fungi can cause different problems such as rashes, infections or allergies, depending on the species of fungus present. For example, ringworm is a fungal infection (not a worm) that causes itchy skin and a circular rash (shaped like a ring). People can get ringworm if they come in contact with this specific fungal pathogen, such as in public showers or by sharing objects including towels.

Treating fungal pathogens also depends on the type of fungus. Fungal infections on the skin can be treated with anti-fungal creams, but sometimes it may require medication.

Pathogenic protists

Pathogenic protists, or protozoa, can cause disease in their hosts because they feed off the nutrients of host cells. Like fungi and bacteria, the type of disease depends on the type of pathogen. Protists that belong to the Trypanosoma genus cause 'sleeping sickness', in which the brain swells causing confusion, personality change and sleepiness. This disease is spread by an insect **vector**. When a tsetse fly bites and sucks the blood of a human, the human can become infected or pass on the infection. Malaria is another pathogenic protist that is spread by mosquito vectors.

vector
a carrier that can transfer an infectious pathogen from one host to another

Table 1 Common bacterial pathogens

Bacteria	Description
Tuberculosis (TB) 	TB is a respiratory disease caused by *Mycobacterium tuberculosis* (MTB). It affects the lungs of the host and can cause a severe cough and fever. The pathogen spreads when an infected person coughs or sneezes.
Salmonella 	Salmonella bacteria live in animal intestines and can contaminate the food we eat during the preparation process. Consuming this pathogen can lead to food poisoning, with symptoms including vomiting, diarrhea, nausea and fever.



Figure 2 A tsetse fly is a vector for sleeping sickness. It can pass the pathogen on from human to human.

Check your learning 14.5

Recall and explain

1 What is a pathogen?
2 **Identify** the three groups of living pathogens.
3 **Explain** why a virus is not considered a micro-organism.
4 **Identify** a way that micro-organisms, other than pathogens, can be harmful.

Analyse and apply

5 **Predict** how an algal bloom in a lake could harm that habitat.
6 **Propose** two ways you could avoid getting the bacterial pathogen that causes salmonella.

Evaluate and create

7 **Investigate** one pathogen that is not described in this chapter. How does it harm living organisms? **Explain** what can be done to prevent harm or treat the effects of this pathogen.

Skills builder: Processing and analysing information

8 A population of fish live in a local lake that has recently developed an algal bloom. **Examine** Figure 3.
   a What relationship does this graph show? (THINK: What information can you find from the graph titles and labels?)
   b **Explain** what is happening to the lake's fish population. (THINK: What trend can you observe on this graph?)

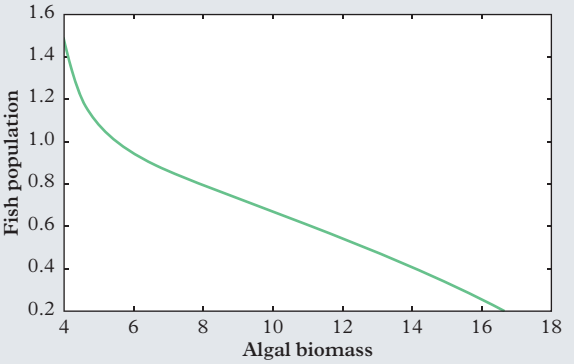


Figure 3 Graph measuring fish population with algal bloom

14.6 Human activity can impact ecosystems

In this topic you will learn that:

- human activities can affect interactions in food chains and food webs.



Figure 2 European wasps are a threat to many Australian ecosystems.

urban sprawl
the spread of urban areas into rural areas

Organisms are constantly having an impact on the environment around them (their habitat). They use resources such as food and water and, in turn, provide resources for other organisms. Humans are certainly no exception. Human impact on environments is considerable because of our population numbers and our ability to manipulate our surroundings to suit our needs. We are able to make both positive and negative changes to the environment. Understanding these impacts is the first step to reducing and reversing them.

Deforestation

Our landscape was once covered by patches of different types of habitat, such as swamp, grassland, forest and heath. This variety of vegetation supported many species of animals that moved, reproduced and spread throughout their territories and beyond.

Today, Australians are clearing land at the massive rate of over half a million hectares a year. That is approximately one million football grounds each year. Much of that land is used for our homes, to grow our food or to manufacture products. The food webs that existed in these areas have been changed as new predators (dogs and cats) move in and the number of producers decreases.



Figure 1 Only one specimen of the Hastings River mouse has ever been found. It is considered extinct due to changes brought about by European colonisation.

Introduced organisms

Introduced organisms may become pests or weeds. For example, the first European wasp in Australia was recorded in Tasmania in 1959, and the wasps are now common there. On the mainland, the European wasp was reported in Melbourne in 1977 and in Sydney in 1978. The wasps may have originally arrived in wood shipments but, with few predators, no diseases and no competition for nest sites, their numbers have increased quickly.

So, how does the European wasp affect a food web? If it had no predators and no competition for nest sites, the European wasp may be able to fit in without affecting other organisms in an ecosystem. However, every living thing, including the European wasp, consumes resources to live. By the end of an Australian summer, each European wasp nest may contain several thousand individuals. The larvae complete their development after being fed a diet that consists mainly of other insects that the workers catch and kill. This means that each European wasp nest has the potential to remove several thousand native insects – often the caterpillars of moths and butterflies – from the environment.

Land degradation

Human activities have led to a degradation of the physical environment. Soil erosion is a major problem caused by the clearing of land for agriculture. In ecosystems with many trees, the soil is stabilised by a dense mat of plant roots. Its surface is covered by a layer of leaf litter, which protects the soil surface from being eroded by wind and water. Water from rainfall is quickly absorbed through the top layers of soil.

Once land is cleared of trees for agriculture, there is little to protect the soil from the actions of wind and water. Grazing by animals with hard hooves, such as cattle, compacts the soil.

This slows the absorption of water into the soil, increasing the amount of water run-off. This, in turn, erodes the soil. Wind also contributes to the removal of the nutrient-rich topsoil.

Urban sprawl

More than half the world's population lives in cities. The population in the world's urban areas has grown by more than one billion people since the 1970s. Much of this growth has contributed to a phenomenon, or process, known as urban sprawl. **Urban sprawl** means the spread of urban areas into rural areas, such as farmland, forests and coastal lands that lie on the outer edges of cities. Urban sprawl increases the distance between the city centre and its outer edge. Urban sprawl is common in rapidly developing cities or those with large populations.



Figure 3 Urban sprawl around many of Australia's capital cities is on the increase.

A changing climate

Human activities are contributing to more significant changes to weather and climate. These changes can have a huge impact on ecosystems. In alpine areas, changing rainfall and temperature patterns alter the amount of suitable wet alpine habitat. Climate change also impacts ocean habitats. An increase in excessively high water temperatures makes the ocean more acidic. This impacts on reefs by causing 'coral bleaching'.

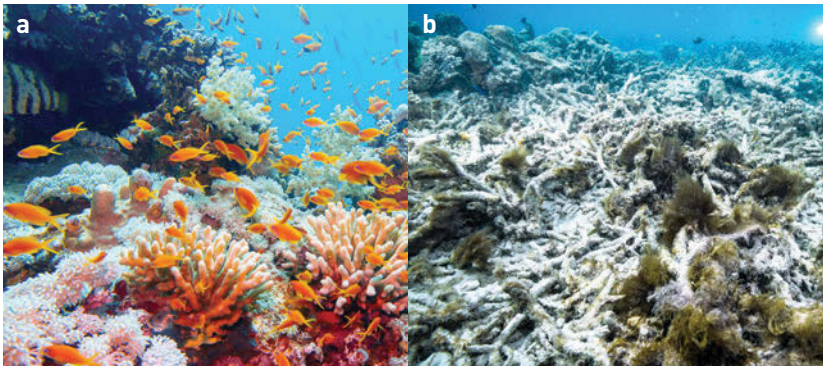


Figure 4 a The Great Barrier Reef; **b** the effects of ocean acidification due to excessively high temperature

Check your learning 14.6

Recall and explain

1 **Identify** an example of an introduced animal species to Australia.
2 **Define** the term 'urban sprawl'.

Analyse and apply

3 **Predict** how urban sprawl could impact on an ecosystem on the outer edge of a city.
4 Why do you think some animals and plants can become pests when introduced to Australia? **Explain.**

Evaluate and create

5 Create a table with the headings 'Problems' and 'Solutions'. In the 'Problems' column, list the types of things that people do that affect wildlife, such as building homes and roads and cutting down trees. In the 'Solutions' column, provide some solutions to each problem.
6 One way to control an introduced organism is to introduce another organism that eats it. This is called biological control. When it works, it can be very good. However, sometimes things can go wrong and the organism introduced to help the problem becomes a much bigger problem. Research the introduction of the prickly pear plant and the cane toad. How successful was each biological control?

Skills builder: Questioning and predicting

7 Choose one of the issues outlined in this topic, such as urban sprawl. **Identify** a question that you could investigate using secondary sources. (THINK: What would you like to know more about? Is the question specific enough to answer objectively?)

14.7 Humans can manage the impact of natural events on ecosystems

drought
a prolonged period of abnormally low rainfall

desertification
the process by which fertile land becomes desert as a result of drought, deforestation or inappropriate agriculture

meteorologist
a scientist who studies weather and climate

In this topic you will learn that:

- science and technology can help to manage the impact of natural events.

Human activities impact ecosystems. The effects of these activities are often more obvious when natural events such as drought, bushfires and flooding occur. But as scientists learn more about ecosystems, they can use their understanding and experience to manage the effect of these natural events.

Drought

All organisms require water for survival. Without it, ecosystems collapse. During times of **drought**, plants wilt and die due to a lack of water. And as the producers in an ecosystem disappear, there is less food available for consumers. This impact continues along the food chain.

Water is also essential for the breakdown of organic matter in the soil. A reduction in soil quality leads to increased erosion and wildfires. If a drought is severe enough, soil that was once fertile can become so dry over time that it becomes permanently like a desert. This process is called **desertification**.



Figure 1 Long periods of drought can cause desertification.



Figure 2 This desalination plant in Victoria was built to combat water shortages during droughts.

Managing droughts

Understanding and predicting the weather is an important part of preparing for droughts. Today, **meteorologists** are able to observe and forecast weather patterns using satellite images. This allows for greater time and resources to be allocated to drought management, which will in turn minimise the impact of the droughts on Australian ecosystems. Australia is also home to some of the biggest dams in the world. Because we receive less consistent rainfall than some other countries, we need to be able to collect and store more water.

But some scientists are concerned that climate change will increase the number, length and severity of droughts. In these cases, scientists and engineers have developed a number of options for obtaining water, such as:

- groundwater bores – drilling bores into the ground to access water beneath the surface
- desalination plants – purifying water, such as from the ocean, to make it drinkable
- water-efficient technology – creating appliances and equipment that use less water, such as washing machines or shower heads.

For some farmers, though, there is still not enough water to support their crops and livestock in times of drought. The challenge still exists for scientists and governments to develop a solution to this problem.

Bushfires

Australia has been devastated by bushfires in recent times. They are a common occurrence across the country, particularly in summer. During times of drought, heat and wind, there is a higher risk of bushfire. Bushfires can be started by many things, including lightning strikes, stray flames or sparks.

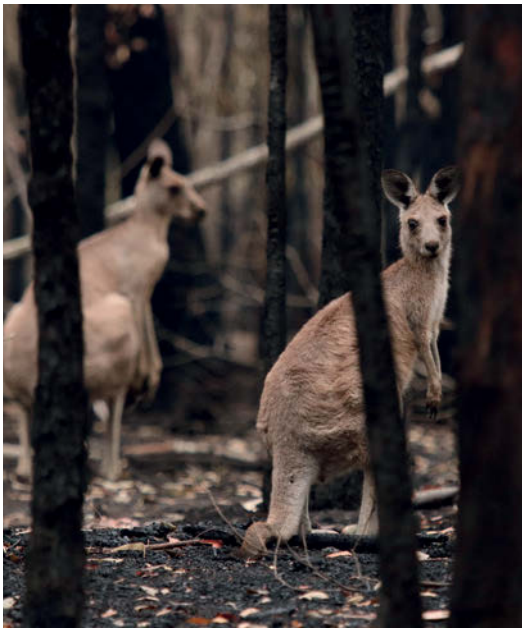


Figure 3 Kangaroos are left without a source of food after a bushfire destroyed their habitat.

Sadly, some bushfires are lit by people. Deliberately lighting bushfires is illegal because of the huge impact it can have, such as loss of property and homes, loss of habitats and, in very sad cases, loss of life.

The impact of bushfire can carry on long after the bushfire has been extinguished. Some Australian plants benefit from bushfires because it helps their seeds to germinate. But if a fire burns with too much intensity, it can kill the plant and its seeds entirely. With fewer producers left in the food chain, this leaves the consumers with less food to survive on.

Managing bushfires

There are many strategies that scientists and the Australian fire authorities can use to prevent and extinguish bushfires. One common strategy is controlled back burning. This involves deliberately lighting small fires in cool, still conditions to reduce the amount of vegetation that could fuel a bushfire in hot windy conditions when it can burn out of control. Aboriginal and Torres Strait Islander people have been managing vegetation in this way for many years. Fire stick farming is a practice that involves burning controlled fires to prevent the build-up of dense vegetation and encourage new plant growth. In recent years, scientists have developed fire-fighting drones that can be used to start controlled back burns in isolated areas. The drones are also used to monitor fire fronts and allow the best use of resources to fight the fires.

Australian scientists recently used satellites to predict droughts, and therefore greater risk of bushfire, up to five months in advance. Satellites collected data on the amount of surface and sub-surface water in the soil. This information was used to predict how droughts would influence the risk of uncontrollable bushfires. This allows us to better prepare for bushfires in advance.



Figure 4 Fire authorities are allowed to conduct controlled burns to manage the spread of bushfires.



Figure 5 Fire authorities can now use drones to help them monitor and manage bushfires.

Check your learning 14.7

Recall and explain

1 **Recall** three common natural events in Australia.
2 **Describe** one impact of drought on an ecosystem.
3 **Explain** how bushfires may result from climate change.
4 **Recall** how scientists are using technology to manage one natural event.

Apply and analyse

5 Controlled burns are typically done in winter. **Propose** a reason for this.
6 **Propose** two ways you could lessen the impact of drought at home or school.

Evaluate and create

7 **Investigate** the cause of floods and how humans can manage their impact using science and technology. Communicate your findings as a report or presentation.

Skills builder: Communicating

8 **Investigate** what strategies the rural fire service (RFS) has in place to manage bushfires when they happen. **Construct** a graphic organiser, such as a table or flow chart, to record some of these strategies and how they work.

14.8 Scientific knowledge has influenced agriculture

In this topic you will learn that:

- scientific knowledge helps us to farm and breed animals more efficiently
- reproductive technologies are used in agriculture to improve desired characteristics, including increased yield and, in more modern times, develop more sustainable practices.

selective breeding
the breeding of two individuals chosen for for their particular traits

Agriculture first began independently in different parts of the world between 10 000 and 20 000 years ago, which gave humans more stable access to food and other resources. From that moment on, humans have influenced and manipulated thousands of different animal and plant species to meet their needs.

Animal husbandry

animal husbandry
the science of breeding and caring for farm animals

yield
the amount produced

artificial insemination
the introduction of sperm from a male with desirable traits into a female

Animal husbandry refers to the breeding and raising of animals for specific purposes, such as for their wool, eggs or meat. As scientific knowledge increases, the agricultural industry has been able to improve their **yield** (the amount produced).

Animal husbandry techniques include selective breeding and artificial insemination. It also includes attempts to clone or genetically modify animals. However, this is considered more ethical in plant agriculture.

Selective breeding

Selective breeding involves choosing which two organisms to breed together in order to keep, lose or enhance characteristics that would appear in their offspring. For example, a cow that is known to produce lots of milk would be chosen to breed with a bull that is known to produce strong, healthy offspring. This would mean that there's a greater chance of producing female offspring that are strong, healthy and good milk producers.

Artificial insemination

As scientific understanding of genetics and reproduction improves, techniques such as artificial insemination have become more common. **Artificial insemination** involves placing the male animal's sperm directly into the female's uterus. As a result, sperm banks



Figure 1 A Belgium blue selectively bred for muscle (meat).



Figure 2 Dolly the sheep was the first cloned mammal (born in 1996). She is now on display in the National Museum of Scotland.

for animals have been developed. The desired frozen sperm can be purchased and sent to the owner of the female animals, where it will be used to create offspring, hopefully with the desired characteristics.

Animal cloning

Cloning is a technique that ensures the chosen characteristics are passed on to offspring. Cloning works by taking the genetic information from the nucleus of a body cell of a male or female organism. This information is placed inside a female egg that has had its genetic information removed. The 'new' egg is then placed in a surrogate mother until birth. In this process, the offspring will be genetically identical to the original animal.

Currently, due to a combination of legal requirements, ethical issues and scientific complications, cloning and genetic modification in animal husbandry are not common.

Crop cultivation

Plants are important to humans as a food source and for feeding livestock. Plants provide timber, shelter and shade, paper and many other useful materials and medicines.

Plant **agriculture** involves the large-scale cultivation of crops. **Horticulture** is a branch of agriculture that typically focuses on small garden crops, particularly fruits, vegetables and ornamental plants. Horticulture involves a lot of scientific experimentation and research that can improve things like crop yield, drought resistance or the colour or flavour of fruit.

Selective breeding and artificial pollination in plants

Selective breeding also applies to plants. As with animals, selective breeding involves taking a male sex cell (pollen) from a plant

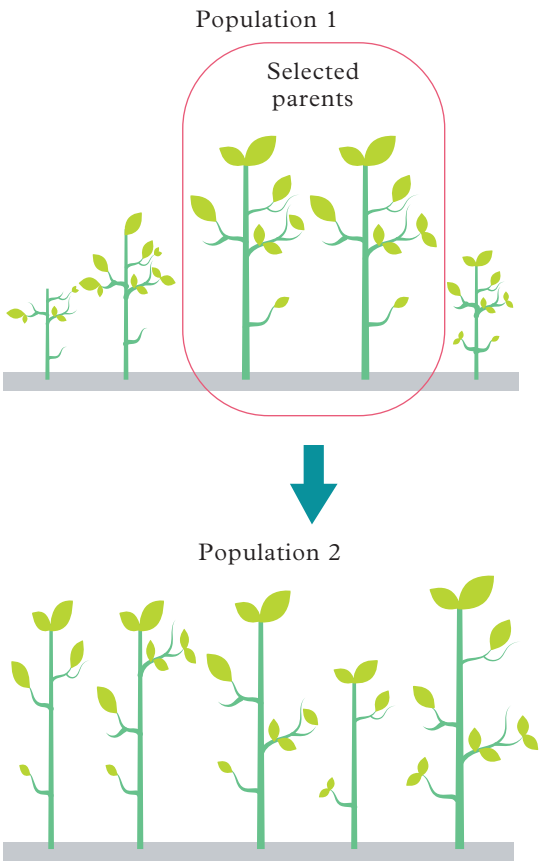


Figure 3 During the selective breeding process, humans choose two parent organisms that have desirable characteristics. The offspring of the selected parents should also have these characteristics.

with favourable characteristics and pollinating another plant with desirable traits. For example, a type of wheat that is known to survive frost or disease can be deliberately cross-pollinated with a type of wheat that produces high-quality grains to hopefully produce a combination of both features. There are also now many thousands of varieties of apples that have been selectively bred for colour, shape, taste and size (see Figure 4).

cloning
the process of producing a genetically identical copy of an organism

agriculture
the large-scale cultivation of animals and crops

horticulture
a branch of agriculture that typically focuses on small garden crops, particularly fruits, vegetables and ornamental plants



Figure 4 The fruit we see in the supermarket are sometimes selectively bred for better flavour or longer shelf life.

cuttings
the process where segments of a plant, usually the stem, are cut and inserted into water or a growth medium

budding
the process where a single bud of the desired plant is inserted into a slit in the bark of a compatible root stock

grafting
the process where a number of buds, shoots or twigs are placed on the stock plant

layering
the process where part of the stem is exposed to soil or moisture-holding materials, such as sphagnum moss, to achieve the best root development

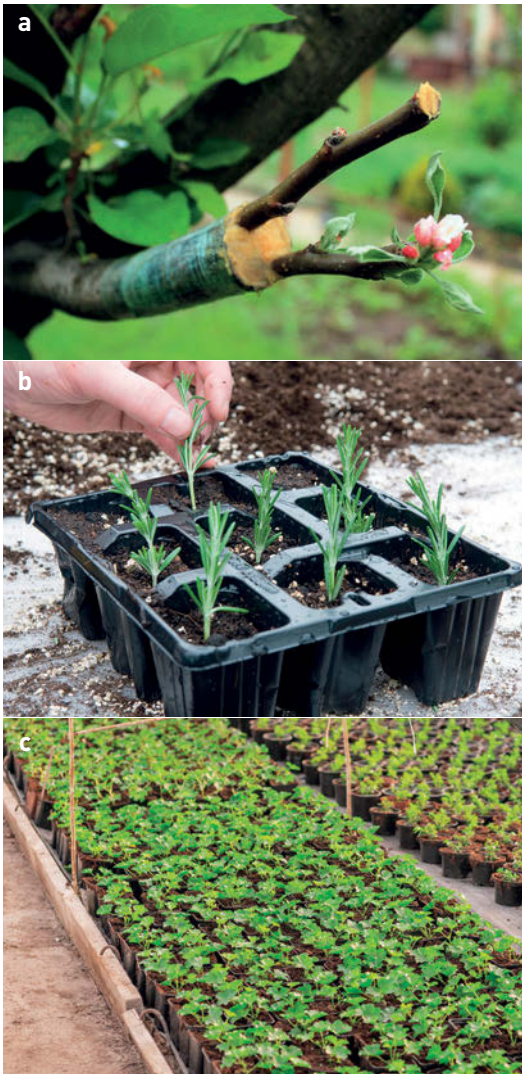


Figure 5 Vegetative propagation of plants: **a** grafting, **b** cuttings and **c** mass production

Plant cloning

While cloning of animals is a controversial topic, humans have been cloning plants for hundreds of years – it is the basis of our agricultural and horticultural industries. Scientists have developed an understanding of the natural ways that plants reproduce, and have been able to manipulate and enhance these processes to produce many of the plants we use in agriculture and horticulture.

Plant cloning techniques include:

- **Cuttings**: Segments of a plant, usually the stem, are cut and inserted into water or a growth medium. New roots will grow, and the plant is eventually transplanted.
- **Budding**: A single bud of the desired plant is inserted into a slit in the bark of a compatible root stock. Disease-resistant root stocks can be used to improve plant health in the new plant.
- **Grafting**: A number of buds, shoots or twigs are placed on the stock plant. This technique can be used to produce one tree, such as a peach tree, but with branches of different varieties of peach that ripen at different times and have different desirable qualities.
- **Layering**: Part of the stem is exposed to soil or moisture-holding materials, such as sphagnum moss, to achieve the best root development. Once the root system is sufficiently established, the offspring can be severed from the parent.

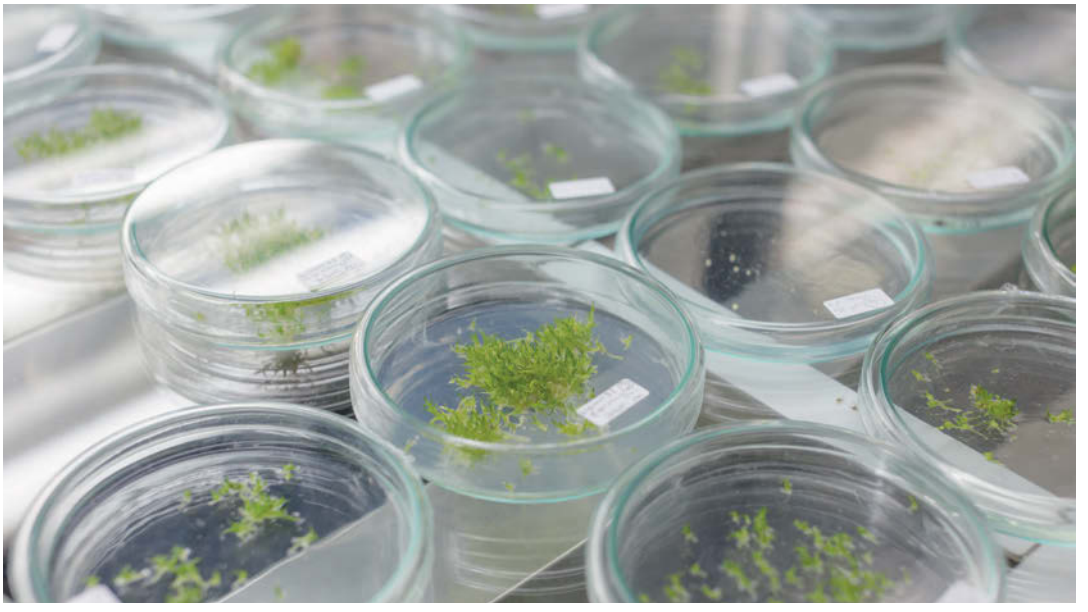


Figure 6 Tissue culture clones plants in a laboratory environment.

A more complicated way to clone plants is by growing a sample of the plant in the lab, called tissue culture. In this process a sample of the plant's cells are placed in agar jelly that contains hormones and nutrients to help it grow.

Benefits and limitations of selective breeding

Diversity in plants and animals refers to the variety of genetic material in a single population or species. When a characteristic, such as milk production in cows, is used for selective breeding, any cow that does not produce 'enough' milk is not encouraged to breed. This often means the genetic material from that cow is not passed on to the next generation. Instead, the next generation of calves will only have genetic material from the few cows that meet the milk production criteria. As a result, there is less variation in the genetic material. While this means the cows have the same positive characteristics, it also means the populations share the same weaknesses. They are more susceptible to infections, which can wipe out their entire population.

For example, you may not realise that bananas, the world's most popular fruit, are nearly all genetically identical. The seedless banana fruit we enjoy was a genetic mistake of nature that left the plant sterile. As a result, the plant can only reproduce via cloning techniques. In the mid-1950s the entire world population of bananas was nearly wiped out due to a fungal disease (Panama disease). Although numbers recovered, the concern that a similar event could occur still exists today.



Figure 7 Banana plant with Panama disease.



Figure 8 In the mid-1800s, the population of Ireland relied very heavily on potatoes for food. When a fungus infected the potatoes, the lack of genetic diversity meant that all potato crops were wiped out and about one million people died of starvation.

Check your learning 14.8

Recall and explain

1 **Explain** selective breeding. Give examples in your answer.
2 **Identify** the key steps involved in animal cloning.
3 **Explain** one technique used to clone plants.

Apply and analyse

4 **Assess** the advantages and disadvantages of selective breeding.

Evaluate and create

5 Do you think selective breeding is a good idea? **Justify** why or why not.
6 Research an example of the difficulties faced by breeding flat-faced pug dogs.
7 **Propose** reasons why plant cloning is a less controversial subject than animal cloning.
8 Choose one of the methods of vegetative propagation and research it in detail. Report your findings to the class, perhaps with a demonstration of the technique.

Skills builder: Conducting investigations

9 A group of students want to investigate which method for cloning plants is the most effective. For their method, they decide to plant a cutting from a plant into a pot of soil and measure how many days it takes for the plant to grow to be 30 centimetres tall. **Assess** this method. (THINK: Is it a fair test? Will the method help them to fulfil their aim? Is it a safe method?)

REVIEW

Multiple choice

1 In Figure 1, **identify** which organism is the producer.



Figure 1 A food chain

- **A** Corn
- **B** Mouse
- **C** Snake
- **D** Owl

2 In Figure 1, **identify** which organism is the second-order consumer.

- **A** Corn
- **B** Mouse
- **C** Snake
- **D** Owl

3 In Figure 1, **identify** which organism appears to be a herbivore.

- **A** Corn
- **B** Mouse
- **C** Snake
- **D** Owl

Recall and explain

4 **Recall** the meaning of the term 'biosphere'.

5 What is the difference between a producer and a consumer?

6 **Explain** why producers are at the beginning of every food chain.

7 What are the three types of symbiotic relationships? Provide an Australian example of each.

8 Outline two ways human activity can be damaging to an ecosystem.

9 **Recall** two ways that micro-organisms benefit ecosystems.

10 **Recall** two ways that micro-organisms can harm ecosystems.

11 **Describe** the role of a decomposer in an ecosystem.

12 **Outline** two strategies that we use in Australia to manage the impact of bushfires.

13 **Outline** two strategies that help us to manage drought better in Australia.

14 What is animal husbandry? **Explain** and **identify** two techniques that are associated with animal husbandry.

Apply and analyse

15 **Examine** Figure 2.

- **a** **Construct** a food chain to reflect the interaction you can observe.
- **b** **Propose** a producer for your food chain.



Figure 2 A green tree frog and a grasshopper

16 European rabbits were first brought to Australia in the late 18th century for meat and hunting. Since then they have spread rapidly, grazing on native vegetation and introduced crops. This makes them a pest for both native animals and farmers.

- **a** **Predict** how introducing rabbits Australia would impact the native vegetation.
- **b** The brush-tailed rock wallaby is an endangered species in NSW. It eats the same native vegetation as the European rabbit. **Explain** how the European rabbit could have contributed to the brush-tailed rock wallaby becoming endangered.



Figure 3 A European rabbit is a pest in Australia.

17 **Identify** one advantage and one disadvantage of selective breeding in animals.

18 **Distinguish** between the terms 'ecosystem', 'habitat', 'community' and 'population'.

19 Compile a list of introduced organisms that can be found around your school.
   a Try to find out how the organism came to your area.
   b Does this organism interfere with the local ecosystem? If so, how?

20 With a growing population, humans are requiring more from the land around them. **Describe** three ways in which humans change the environment.

21 **Explain** why a food web is a more accurate representation of an ecosystem than a food chain.

22 **Consider** the food web in Figure 4 in topic 14.2. If the mouse was to become locally extinct, list the possible changes that would occur to the other organisms in the food web.

23 In the same ecosystem, what would have happened if another animal was introduced? Would it matter if the animal was a herbivore or carnivore?

Evaluate and create

24 Imagine a world without spiders. **Describe** what the world would be like. In your answer, consider what spiders eat and what other organisms eat spiders.

25 In some cases, introduced animals, like monkeys introduced to Hobart, fail and never become established. In other cases, they are spectacular 'successes', such as rabbits and foxes across much of southern Australia. In terms of the environment in which these animals live and their interactions with other animals, **explain** why some animals succeed and others do not.

26 Create a poster that illustrates why it is important to protect ecosystems.

27 A simple change to your daily habits, such as reusing and recycling paper at school, can make a difference to ecosystems. Use this example, or another, to **discuss** how your actions impact on biodiversity.

28 In the last 200 years, nearly half of the forest in Australia has been cleared to make way for agriculture, homes and other human activities. **Discuss** the impact this would have on Australia's ecosystems. Using the internet, find three pieces of evidence to support your discussion.

29 **Construct** a table that distinguishes between bacteria, protozoa and fungi. Provide two examples of diseases caused by each group.

30 **Evaluate** the impact of scientific knowledge on crop yields in Australia. What challenges has it helped us to overcome?

31 Organism numbers can decrease for a number of reasons, including loss of habitat, climate change and direct removal by humans. **Describe** an example of each.

32 **Evaluate** how knowledge of previous human activities and their impact on an ecosystem could be used to predict future impacts and minimise harm to the ecosystem.

Critical thinking

33 The 'Australian dream' is a term that has been used to describe the wish of many Australians to own a home on a block of land in the suburbs. What problems have arisen as a consequence of many Australians living this dream?

34 Why do you think it is considered more ethical to clone plants than it is to clone animals? **Explain** your reasoning.

35 Do you consider it okay to step on an ant? What about squashing a spider? How is this similar to killing a larger animal? How is it different? **Justify** your opinion.

Going further

36 Humans have tried a number of methods to reduce rabbit numbers in Australia, including the introduction of a virus that caused serious deformities and led to a slow and painful death. Do you agree with this method? Do you think the people involved knew what the consequences would be before they released this 'biological control'? Find out more about controlling rabbit populations and suggest your preferred method.

37 The balance of nature is very delicate, and changes to the environment or any member of a food web bring about changes throughout the whole system. Food webs are graphical ways of showing eating relationships inside ecosystems. If the food web is changing, so is the ecosystem. Which do you think would be more resistant to change: big complicated ecosystems with numerous species interacting or simple ecosystems with relatively few species interacting? **Explain** your answer.

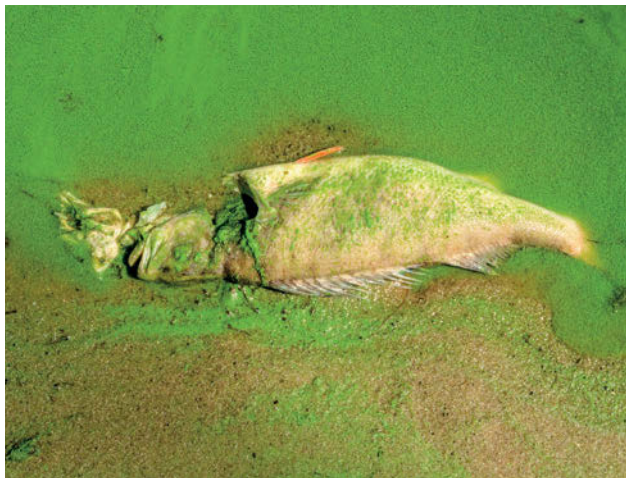


Figure 5 A dead fish caused by algal bloom.

Research

38 Choose one of the following topics on which to conduct further research. Present your findings in a format that best fits the information you have found and understandings you have formed.

»Dog breeding in Australia

Some breeds of dogs are vulnerable to a series of genetic problems, such as difficulty breathing or displaced hips, as a result of decades of inbreeding. Research a breed of dog that has such difficulties. For which features are these pedigree dogs judged in dog shows? What problems have arisen as a result of the inbreeding? What measures are the RSPCA and the Australian National Kennel Council taking to ensure these problems do not continue?

»Mars biosphere

Earth is particularly special because, as far as we know, it is the only planet that sustains life – our biosphere. The biosphere concept has been looked at as a means of long-distance space travel and to colonise planets such as Mars. As a class project, undertake the 'Mission to Mars' project to set up a biosphere on Mars.

» Extremophiles

Extremophiles are organisms that can live in extreme conditions, such as extreme cold or extreme acidity. Many extremophiles are micro-organisms. Find out more about one extremophile micro-organism. Explain what kind of conditions it can withstand.



Figure 6 The tradigrade, also called the water bear, can survive extreme heat, cold and even radiation. It is an extremophile.

Reflect

Now that you've completed this chapter, reflect on your ability to do the following:

	I can do this.	I can't do this yet.
Construct and interpret food chains and food webs, including examples from Australian ecosystems.	☐	☐ Go to page 246–249.
Describe interactions between organisms in food chains and food webs, including producers, consumers and decomposers.	☐	☐ Go to page 250–253.
Describe examples of beneficial and harmful effects that micro-organisms can have on living things and the environment.	☐	☐ Go to page 254–257.
Predict how human activities can affect interactions in food chains and food webs, including examples from Australian land or marine ecosystems.	☐	☐ Go to page 258–259.
Explain, using examples, how scientific evidence and/or technological developments contribute to developing solutions to manage the impact of natural events on Australian ecosystems.	☐	☐ Go to page 260–261.
Describe how scientific knowledge has influenced the development of practices in agriculture, e.g. animal husbandry or crop cultivation to improve yields and sustainability, or the effect of plant-cloning techniques in horticulture.	☐	☐ Go to page 262–265.

Source: NSW Science Years 7–10 Syllabus © NSW Education Standards Authority for and on behalf of the Crown in right of the State of New South Wales, 2018.

THE NATURE OF MATTER

What is matter and how do we observe it?

Have you ever wondered ...

- Why do icebergs float on water and not sink?
- Why do liquids take the shape of the container they are in but solids do not?
- Why does hot chocolate produce steam if it's not water?

15

SCIENCE UNDERSTANDING

In this chapter you will learn how to:

- describe the behaviour of matter in terms of particles that are continuously moving and interacting
- relate an increase or decrease in the amount of heat energy possessed by particles to changes in particle movement
- use a simple particle model to predict the effect of adding or removing heat on different states of matter
- relate changes in the physical properties of matter to heat energy and particle movement that occur during observations of evaporation, condensation, boiling, melting and freezing
- explain density in terms of a simple particle model
- identify the benefits and limitations of using models to explain the properties of solids, liquids and gases.

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Check your Student obook assess for these digital resources and more:

QuizletLive
Compete in teams to test your knowledge.

Assess quiz
Before you start this chapter, assess your science skills.

Check your Teacher obook assess for these digital resources and more:

QuizletLive
Launch a quiz for your students on key concepts in this chapter.

15.1 There are three states of matter

In this topic you will learn that:

- matter is the name given to all substances
- there are three major states of matter – solid, liquid and gas.

Solids, liquids and gases

matter
anything that has mass and volume

There are three major states of **matter** – solid, liquid and gas. Solids, liquids and gases are all around us. Steel, concrete, wood and plastic are all examples of solids. Water and cooking oil are examples of liquids. Carbon dioxide is a common gas – you can see it as bubbles in soft drinks. Air is a mixture of gases. The smell of a barbecue is caused by gases that leave the food as it is being cooked.

Many substances can be found in more than one state. Water is the most common substance that we experience in its different states of matter. In the freezer, liquid water solidifies into ice. On a cold night, frost (solid) forms from water vapour (gas) in the air. On a warm sunny day, puddles (liquid) will evaporate to become water vapour.



Figure 1 This glass of lemonade contains the three states of matter.

Although the ocean and iceberg shown in Figure 2 may look and behave very differently, they are both different forms of water. The ocean is liquid and the iceberg is solid. There is also water vapour in the air. Clouds are made of small liquid water droplets. All of these different states of water are made of the same 'building blocks', or water particles.

Pure water will always be the same anywhere on Earth – or on another planet. Water always has the same properties, no matter where it comes from.

It is usually obvious if a substance is a solid, liquid or gas. However, some substances seem to be made of more than one state of matter. Sometimes we can see the states of a mixture, such as in honeycomb confectionery, which is a combination of solid and gas. But other times it is difficult to tell the state of mixtures. How would you classify slime or jelly?



Figure 2 Solid water floats on liquid water.

INVESTIGATION
15.1: Comparing states of matter
Go to page **393**.



Figure 3 Honeycomb is a combination of solid and gas. Or is it?

Describing matter

The properties of a substance can be measured and are always the same for that substance if it is pure. Solids, liquids and gases have unique properties. Solids do not change their shape and cannot be compressed. Liquids cannot be compressed and change their shape to fit the container holding them. Gases completely fill the container holding them and can be compressed. Some substances are important to us because of particular properties. For example, one property of water is that it can be used to dissolve many other substances. This makes water useful for cleaning clothes, cooking and experiments in a chemistry laboratory.

The properties of substances can be divided into two groups: physical and chemical properties.

- **Physical properties** are what we can observe and measure without changing the substance into something else. Examples of physical properties are colour, texture, boiling point, density, electrical conductivity, heat capacity and how readily that substance can dissolve other substances or be dissolved itself.



Figure 4 Liquid water When most of us think of water, we think of the liquid form that comes out of our taps. Liquid water sits at the bottom of cups and flows smoothly over surfaces. Water can fit into containers of all shapes and sizes. It is flexible.



Figure 5 Solid water When heat is removed from liquid water, the movement of the water slows. The water has been solidified. This is the solid form of water called ice. Like all solids, ice holds its shape even when it is tipped from a container.



Figure 6 Gas water When heat is added to liquid water, the water starts to move faster. Eventually it becomes a gas called water vapour. The gas has much more energy than a liquid or solid. It does not sit at the bottom of a container. Instead it moves freely around the whole container.

physical property can be measured or observed without changing a substance into something else, e.g. colour, boiling point

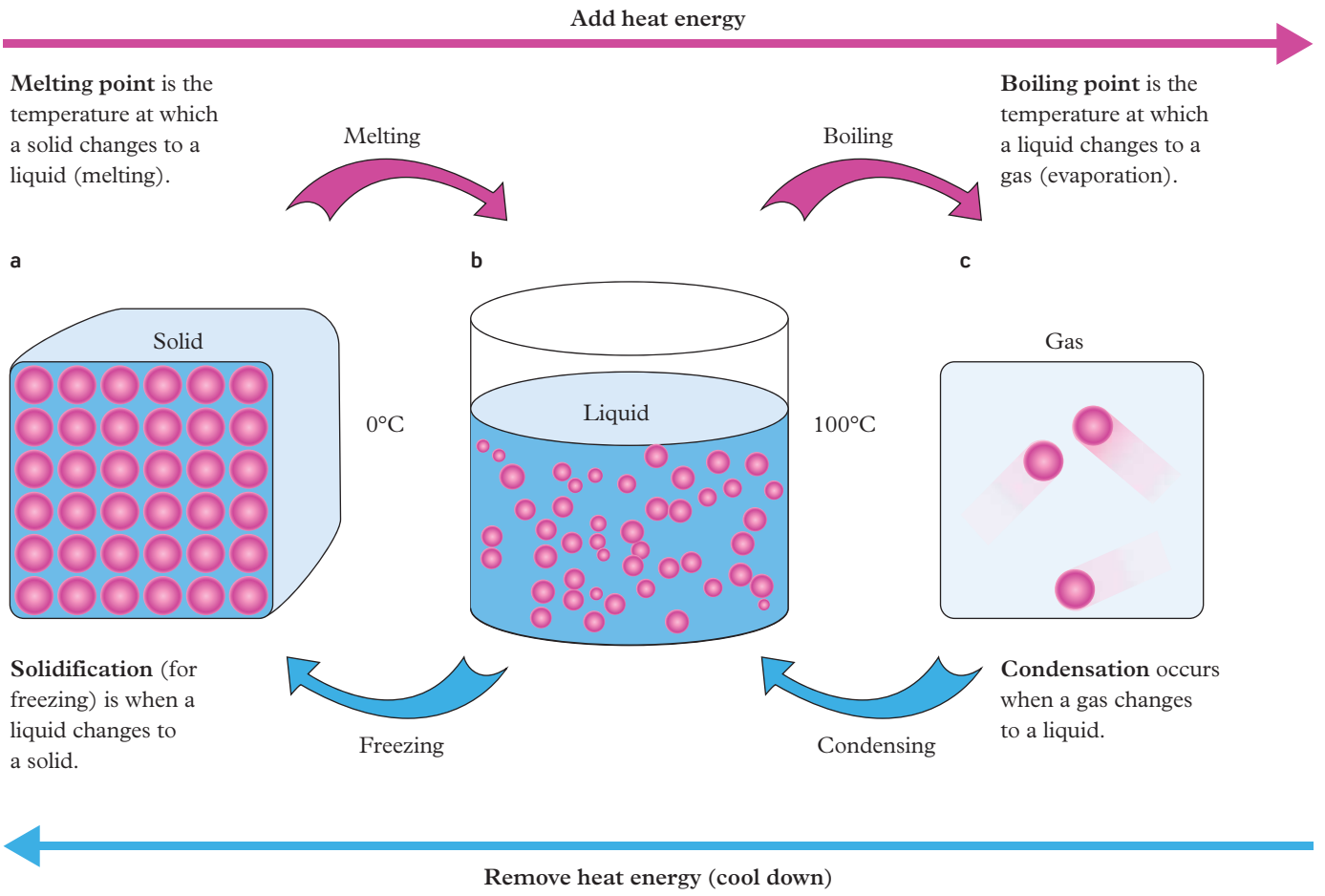


Figure 7 States of matter and their phase changes

chemical property
how a substance behaves in a chemical reaction, e.g. how it reacts with acid

melting point
the temperature at which a solid changes to a liquid

boiling point
the temperature at which a liquid boils and turns to a gas

› **Chemical properties** are what a substance does in a chemical reaction. Examples include how toxic it is, how it reacts with other chemicals, permanent colour change and permanent change of state.

Table 1 Properties of water

Physical property	Value
Melting point	0°C
Boiling point	100°C
Colour	Colourless
Density	1.00 g/mL at 25°C

Changes in state

The temperature that causes water to become a solid is called its freezing temperature. If heat is added back to the solid water, the ice melts. This is called the melting point.

The **melting point** of a substance is the temperature at which a substance changes from a solid to a liquid. The phase change is called melting. Some examples of melting points are water at 0°C, magnesium at 1091°C and fluorine at –220°C.

The **boiling point** of a substance is the temperature at which a substance changes from a liquid to a gas. The phase change is called evaporation. Some examples of boiling points are water at 100°C, magnesium at 650°C and fluorine at –188°C.

The process of making a gas from water is called evaporation. If heat is removed from the steam, the gaseous water slows its movement until it once again forms liquid water. This process is called condensation.



Figure 8 On a cold day, you might find condensation on your windows. This occurs when moisture in the warm air comes into contact with the cold glass, removing heat energy and condensing the water.

Check your learning 15.1

Recall and explain

1 **Describe** what happens to water when it:
   - **a** evaporates
   - **b** condenses
   - **c** freezes.

2 **Explain** what happens to the state of liquid water when it is heated.

3 What is meant by a property of a substance?

4 **Identify**:
   - **a** the melting point of water
   - **b** the boiling point of water.

Apply and analyse

5 **Classify** the following substances according to their state of matter as a solid, liquid or gas, or even a combination of states: ice cream, chocolate bar, clouds, thick smoke, glass, honey, cake or bread, mashed potato, paper, peanut butter (smooth), cling wrap, play dough, sand, steam, slime.

6 **Classify** the following properties as physical or chemical: malleability (the ability to be hammered into flat sheets), the ability to explode, the amount of vapour released at different temperatures.

7 **Compare** the similarities and differences between physical and chemical properties.

8 Select a common substance, such as cling wrap or vinegar. Name some of the physical properties of this substance.

Evaluate and create

9 A student claimed a frozen drink bottle was leaking because condensation had formed on the outside of the container. Has the student made a correct inference? **Justify** why or why not.

10 Plasma is the fourth state of matter. **Investigate** the properties of plasma and write a short summary (50 words or less) to compare with your class.

Skill builder: Processing and analysing information

11 **Interpret** the table. Which substance has the:
   - **a** lowest melting point
   - **b** highest melting point
   - **c** lowest boiling point
   - **d** highest boiling point?

Substance	Melting point (°C)	Boiling point (°C)
Water	0	100
Iron	1535	2750
Lead	327	1750
Mercury	–39	357
Table salt	805	1413
Oxygen	–219	–183
Nitrogen	–210	–196

15.2 Models are used to explain matter

In this topic you will learn that:

- scientists throughout history have used models to explain matter
- models to explain matter have both benefits and limitations.

theory
an explanation of a small part of the natural world that is supported by a large body of evidence

The particle **theory** of matter has been tested and refined by scientists for more than 2000 years.

Democritus

Over 2400 years ago, Greek philosopher Democritus (*c.* 460 – *c.* 370 BCE) put forward the idea that all matter is made up of particles. He proposed that if you were to cut up these particles into smaller and smaller pieces, you would eventually have tiny particles that could not be cut up any more. Democritus called these particles *atomos*, which is Greek for 'indivisible'. This is the origin of the word '**atom**'.

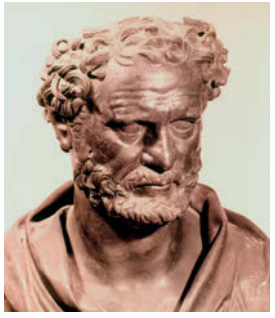


Figure 1 Democritus proposed that all matter was made of atoms.

atom
smallest particle of matter that cannot be created or destroyed

John Dalton

It was not until 2000 years later, in the early 1800s, that English chemist John Dalton (1766–1844) developed Democritus's idea further. Dalton's ideas were based on the results of experiments performed by many earlier chemists. Dalton studied these results and proposed a model to explain them. His model was that matter is made of particles. Dalton's key ideas were:

- All matter consists of tiny particles called atoms.
- Atoms cannot be created or destroyed.
- All atoms of the same element are identical, but different from atoms of other elements.
- When atoms combine to form compounds, each atom keeps its identity.
- Atoms combine to form compounds in simple whole number ratios. For example, hydrogen and oxygen combine in a ratio of 2:1 to form water, now written as H_2O.



Figure 2 John Dalton developed Democritus' ideas about particles.

Modern chemistry and the particle model

The new understanding provided by Dalton encouraged scientists to find out more and more about these tiny particles, eventually leading to the branch of science now called **chemistry**.

We can add some new ideas to Dalton's list to help us explain matter:

- Particles are too small to be seen.
- Particles are always moving. When it is hotter, the particles move faster; when it is cooler, the particles move slower.
- Particles have mass.
- Particles can join to make larger particles. When they combine, their masses add together.
- There are spaces between particles.
- Forces hold particles together to stop them from separating.

chemistry
a branch of science that deals with matter and changes that take place within it

All these ideas or rules explain how particles act in real substances. The real particles follow these rules in all substances.

The particle model is used to explain why solids, liquids and gases have different properties. That is, that all matter is made of constantly moving, small particles. How much the particles move is based on how much energy they have.

Models have limitations

Models are useful as they allow scientists to visualise molecules and atoms that are too small to see by the naked eye. It also means that some patterns and trends can be more easily observed and explained. Unfortunately, it is difficult for models to include everything we know about atoms. As we discover more and more, models cannot include all of the complex details as they are too complicated. Although the simple models can make it easier for us to learn about particles, they do not tell the full story. For example, the particle model does not acknowledge that particles in different substances can have different properties, or that particles can be different shapes.

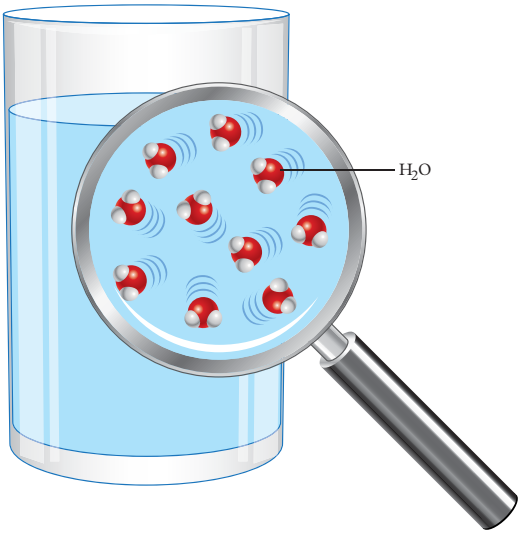
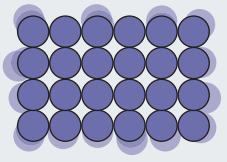
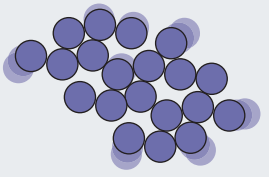
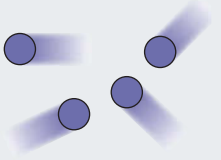


Figure 3 A glass of water is made of molecules. Each molecule contains two hydrogen atoms and one oxygen atom.

Table 1 The different properties of matter

	Solid	Liquid	Gas
Organisation of particles	Close together and in a fixed position	Close together and randomly organised	Far apart and randomly organised; spread to fill the space around them
Movement of particles	Touching each other and vibrating	Touching each other and glide past each other	Bumping into each other and constantly moving
Diagram			

Check your learning 15.2

Recall and explain

1 What was the major difference between the ideas proposed by Democritus and Dalton?

2 **Contrast** an 'idea' with a 'theory'.

Apply and analyse

3 Consider a school assembly. Everyone is sitting quietly in their seats in rows. When the assembly finishes, there is a crowd at the doors pushing to go through them to leave. When outside, the students run off in all directions as fast as they can. **Identify** which parts of this analogy represent a solid, a liquid and a gas.

4 What are some benefits and limitations of the models used in question 5 below to represent states of matter?

Skills builder: Communication

5 Some people use analogies or models to compare states of matter. **Apply** the following situations to represent a state of matter.

- **a** A swarm of bees crawling over one another
- **b** A thousand tennis balls tidily arranged in a large cardboard box
- **c** Eggs in trays in a large egg container
- **d** A school of fish darting in all directions as they avoid a predator

15.3* Particles are always moving

In this topic you will learn that:

- matter is made up of atoms
- according to the particle model, particles are always moving and interacting.



Figure 1 Some of the energy in storms comes from the condensation of vapour into liquid, which we see as rain.

particle model of matter
theory that all matter is made up of very tiny particles

volume
how much space an object takes up, usually measured in litres (L) or millilitres (mL)

Matter is made of extremely small particles called atoms, which are difficult to visualise because they are so tiny. If we imagine the atoms as being tiny balls, we are using an analogy or model. By imagining how the balls behave when the substance is melting, dissolving or heated, we are comparing the atoms to the balls.

The kinetic theory of matter

According to the **particle model of matter**, particles are always moving. The word 'kinetic' refers to the energy of anything that is moving. This means we can use the particle theory of matter to describe how the amount of kinetic energy in each particle determines the state of the matter (solid, liquid or gas). For this reason, the particle model can also be called the kinetic theory of matter.

Particle energy

The movement of people and particles are related to their kinetic (movement) energy.

- When people are sitting quietly, they have little kinetic energy. This is like a solid, where the particles only vibrate.
- In a crowd, people are standing and moving around and have more kinetic energy. This is like a liquid, where the particles jostle about. Particles in a liquid have more kinetic energy than particles in a solid.
- When people are running, they have much more kinetic energy. This is like a gas, where the particles move fast and on their own. Particles in a gas have the highest amount of kinetic energy.

Using the kinetic theory of matter

The kinetic theory of matter can be used to explain many of the observations and measurements that we make about the substances around us.

Mass is the amount of matter in a substance and is measured in kilograms (kg). Mass depends on the number of particles and the mass of each individual particle.

A particular **volume** of solid or liquid has a greater mass than the same volume of gas because it has more particles in it. For example, a container of liquid nitrogen is much heavier than the same-sized container of nitrogen gas.

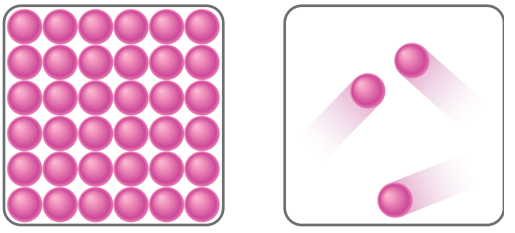


Figure 2 A container of a solid has more particles than the same container of gas.

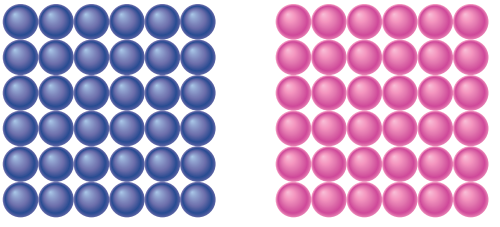


Figure 3 Lead atoms have a greater mass than aluminium atoms.

A piece of lead has a much greater mass than the same-sized piece of aluminium. Both are metals made of atom particles that are packed closely together. The difference is the mass of each atom particle. Lead atoms have a greater mass than aluminium atoms.

CHALLENGE
15.3: Making a cuppa
Go to page **394**.

Diffusion

When the lid is taken off a bottle of perfume, the smell of the perfume spreads throughout the room. This occurs without any breeze or wind and is called **diffusion**. Another example of diffusion is tea spreading out from a tea bag in a cup of hot water. Stirring the cup of tea will mix the particles and speed up the rate of diffusion.

Diffusion occurs fastest in gases. This is because the particles in gases are moving freely and quickly, and there is plenty of space between them. The particles in a gas will spread out quickly and take up all the space they can.

In liquids, the particles jostle against one another. They do not move far before colliding with another particle. As a result, particles in a liquid do not move very far or very fast. Diffusion in liquids is slow.

In solids, the particles are locked into position. The particles vibrate but cannot move to a new location. So, the particles in a solid cannot spread out and diffusion does not occur in solids.

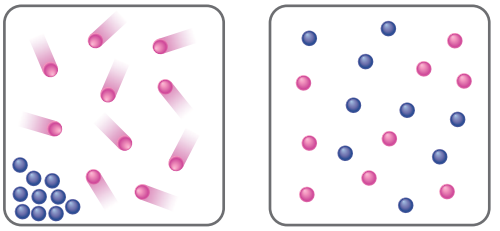


Figure 4 Before (left) and after (right) diffusion in a gas

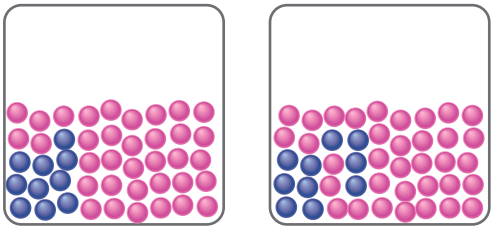


Figure 5 Diffusion is slow in liquids.

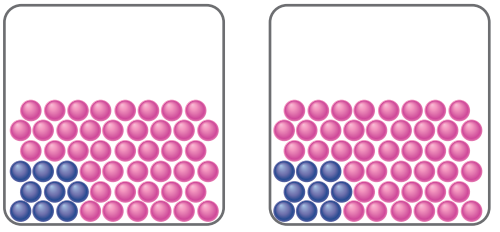


Figure 6 Solids don't diffuse.

diffusion
the spontaneous spreading out of a substance through a liquid or gas, e.g. the diffusion of perfume in air

Check your learning 15.3

Recall and explain

1 Is there any difference between the particle model of matter and the kinetic theory of matter? **Explain** your answer.

2 **Explain** the meaning of the word 'kinetic' in the kinetic theory of matter.

3 From highest to lowest, rank the states solid, liquid and gas in order of energy content.

4 **Explain** what is meant by 'mass'.

5 **Recall** how the kinetic molecular theory (or particle model) of matter explains the different masses of different substances.

Apply and analyse

6 **Explain** why a lump of lead has a greater mass than a lump of wood.

7 How does the kinetic molecular theory of matter explain diffusion in:

a liquids **b** gases?

Skills builder: Conducting investigations

8 Harry was asked to investigate how different factors affect the rate of diffusion in liquids. To test this, he placed a tea bag in one cup of hot water and timed how long it took the tea to completely diffuse through the water. He recorded the time and repeated the exact method again.

a Will Harry's method help him to investigate different factors? **Explain** your reasoning. (THINK: What are the different factors (independent variable) that Harry was testing? Does his method compare factors?)

b **Propose** how Harry could improve his method? (THINK: How can Harry make this a fair test, including independent, dependent and controlled variables?)

15.4 The particle model can explain the properties of matter

In this topic you will learn that:

- particle movement helps to explain the physical properties of matter
- physical properties of matter include strength, hardness, viscosity, compressibility and density.

Understanding how particles move can help us explain the physical properties of matter. This includes how much force the substance can withstand (strength), its ability to scratch other objects (hardness), its thickness (viscosity), how much it can be compressed (compressibility), and the number of particles in a volume (density).

tensile strength
the measure of the flexibility of the links or bonds between particles

compressional strength
the capacity to withstand compression

Strength

The idea of strength can be considered in different ways. A rubber band is easily stretched, but what about a piece of wire? Different wires made of different metals will break if stretched. **Tensile strength** is a measure of the flexibility of the links or bonds between the particles. The bonds between the particles in steel are stronger than those between tin particles. Another type of strength is **compressional strength**. Substances that can withstand large forces without being crushed have a high compressional strength.



Figure 1 Reinforced concrete combines the tensile strength of steel with the compressional strength of concrete.

Hardness

Hardness is the ability of a substance to scratch another substance. An iron nail will scratch a plastic ruler because the iron is harder than plastic. However, the iron nail will not scratch glass because the iron is softer than glass. The order of hardness is glass, then iron and then plastic.

Hardness is not the same as strength. A very hard substance may shatter easily. If this happens, the material is described as 'brittle'.



Figure 2 Glass is a hard, but brittle, substance.

The particle model of matter explains hardness in terms of the forces that hold the particles together. The particles in hard substances are held together very strongly and it is difficult to separate them. In plastic, the particles are not held together as strongly and can be removed or scraped off. Therefore, plastic is not a hard substance.

Viscosity

Viscosity is the thickness or 'gooiness' of a liquid. It describes how easily the particles move around one another. Viscous liquids are hard to pour. Water has a low viscosity, cooking oil is more viscous and honey is very viscous. Engine oils used in engines have different viscosities.



Figure 3 Engine oils are labelled with viscosities.

Compressibility

Compressibility refers to the ability of a substance to be compressed. You can test for compressibility when substances are in a plastic syringe.

If you put your finger over the end of a syringe, you can compress the air inside it. However, if you replace the air with water, you cannot compress the water. Similarly, if you filled the syringe with sand, you would not be able to compress it.

compressibility
the ability of a substance to be compressed (squashed); gases can be compressed but solids and liquids cannot

viscosity
a measure of how slowly a liquid changes its shape; the thickness of a liquid

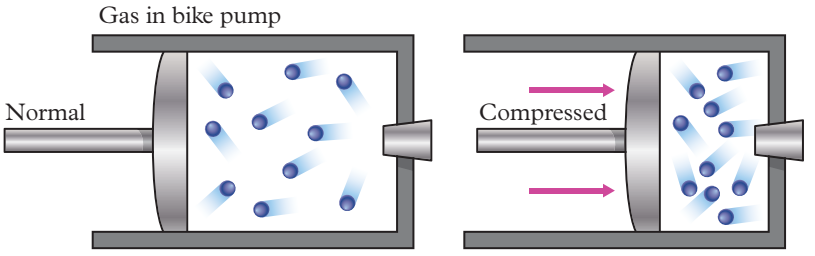


Figure 4 Compression reduces the space between particles.

In solids and liquids, there are no air spaces between the particles, so it is not possible to compress the particles together any closer. Solids and liquids are said to be incompressible. Gases, like air, can be compressed. This is because the particles are spread out and there is space between them.

Check your learning 15.4

Recall and explain

1 **Recall** the meaning of the following physical properties.
   - **a** Strength
   - **b** Hardness
   - **c** Viscosity

Apply and analyse

2 Rank the following in order of compressibility: solid, liquid, gas.

3 If you placed a highly viscous liquid, such as oil, into a water pistol, what would be the effect? **Explain** your reasoning.

4 What would happen to a polished wooden table if you rubbed it with sand? **Explain** by using the idea of hardness.

Skills builder: Problem solving

5 Imagine that you are selecting a substance to use to make a protective case for a mobile phone. What physical properties would you consider when choosing your substance? **Explain** your reasoning.

15.5 Density can be explained by the particle model

In this topic you will learn that:

- density is the amount of matter in a certain volume – that is, the 'heaviness' of a substance.

density
the number of particles (mass) in a volume

One way of comparing the 'heaviness' of two substances is to compare their density. **Density** is the mass of a certain volume of a substance. The density of a substance will affect its properties, such as its ability to float. Density is the mass divided by volume. It is often measured in grams per millilitre (g/mL).

One litre of water is heavier than 1 litre of air. We say that water has a greater density than air. Sand has a greater density than water or air, but a lower density than lead. The densities of some common substances are given in Table 1.

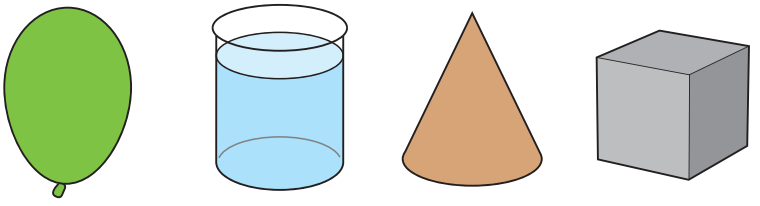


Figure 1 Density compares the mass of objects of the same volume.

The particle model of matter explains density in terms of both the mass and the closeness of the particles. Gases always have a low density because there is a lot of empty space between the particles. Solids normally have the highest density because there is no space between the particles.

Video
Calculating density



Figure 2 A hydrometer is used to test the density of beer.

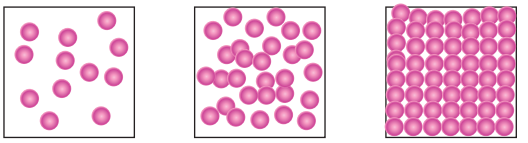


Figure 3 Gases have a low density.

Table 1 Densities of some common substances

Substance	Density (g/cm³)
Air	0.001
Foam rubber	0.05
Wood	0.30
Oil	0.75
Water	1.0
Steel	7.8
Iron	7.8
Lead	11.3
Mercury	13.6

Calculating density

The density of an object can be calculated by dividing its mass by its volume:

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

The unit for density is reliant on what units are used for both the mass and the volume.

- If grams (g) are used for mass and millilitres (mL) are used for volume, the units for density would be g/mL.
- If kilograms (kg) are used for mass and cubic metres (cm^3) are used for volume, the units for density would be kg/cm^3.

Worked example

Calculate the density of a glass that has a mass of 100 g and volume of 35 cm^3.

Solution

The question gives the mass and volume, so we can place these values into the formula for density:

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$
$$= \frac{100}{35}$$
$$= 2.8 \text{ g/cm}^3$$

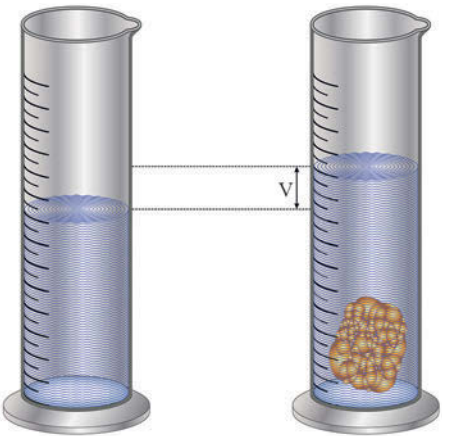


Figure 4 Calculating the volume of an irregular object

Displacement

If an object has an irregular volume that can't easily be calculated using volume = length × width × depth, a technique called 'displacement' can used. The object is placed first in a measuring cylinder of known volume and then in the measuring cylinder. The change in volume (v) is the volume of the object and its units are mL (see Figure 4).

Sink or float

Objects with lower density float on liquid if the liquid has a higher density. For example, in Figure 5 a piece of cork is floating on water. This is because the water has a higher density than the cork. On the other hand, there are coins that have sunk to the bottom of the water. This is because the coins have a higher density than the water.



Figure 5 Cork floats in this glass because it has a lower density than water. The coins sink because they have a higher density than water.

Check your learning 15.5

Recall and explain

1 **Explain** density in terms of the particle model.

2 **Explain** why gases have a much lower density than solids and liquids.

Apply and analyse

3 **Examine** Figure 6, which contains oil, liquid water and ice cubes. Use the particle model to **explain** why the ice is floating in between the oil and water.

4 **Suggest** why a blown-up balloon would float on water, but a bowling ball the same size would sink.

5 A block of copper with a volume of 277 cm^3 has a mass of 2.5 kg. **Calculate** the density of the copper block using the units g/cm^3.



Figure 6 Water, ice and oil in a beaker

Skills builder: Questioning and predicting

6 Use Table 1 to **predict** what will float or sink if the following pairs were in the same container.

- **a** Steel and oil
- **b** Iron and water
- **c** Wood and water
- **d** Foam rubber and oil

15.6 Increasing kinetic energy in matter causes it to expand

*

In this topic you will learn that:

- an increase or decrease in the amount of heat energy possessed by particles changes the way they move.

When you heat matter, you are passing on heat energy to the particles. This means the particles start moving faster. The kinetic energy of the particles increases. This can be used to explain melting and boiling.

Heating particles



Figure 1 Vaporisation explains steam rising from soup.

Gold is usually a solid at room temperature (20°C). Like all solids, the particles in gold are packed tightly together. When solid gold is given heat energy, the gold particles start vibrating faster and faster. When the temperature reaches 1064°C, the particles have enough kinetic energy to move around one another, just like the particles in a liquid. The gold has melted.

If you continue heating the gold, the particles continue to gain kinetic energy, move faster and take up more space. Eventually, when the temperature reaches 2807°C, the gold particles have enough kinetic energy to break free from the other gold particles and to move off on their own as a gas.

This process can happen in reverse. If the temperature is reduced, the particles will move more slowly. The attraction to other particles will now keep the particles close together. The gas has condensed into a liquid.

As the particles in a liquid lose energy, their movement slows. Eventually, they are held in place by other particles and do not have enough energy to move on their own – they become particles locked into a solid. The liquid has solidified or frozen.

Remember that the main difference between a hot and cold substance is the kinetic energy in the particles.

The differences in the movement of hot and cold particles can be seen in a beaker of water (see Figure 6). As the particles move around, they cause diffusion. If the particles move faster, diffusion should occur faster.



Figure 2 Solidification occurs when a substance cools.

INVESTIGATION **15.6A:** Effect of heat
Go to page 397.

INVESTIGATION **15.6B:** From ice to steam
Go to page 399.

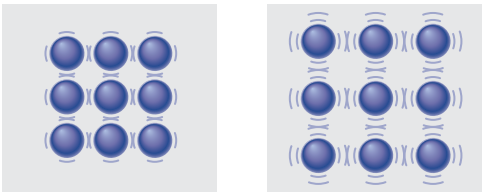


Figure 3 In a hot solid, the particles vibrate harder, faster and wider than in a cold solid.

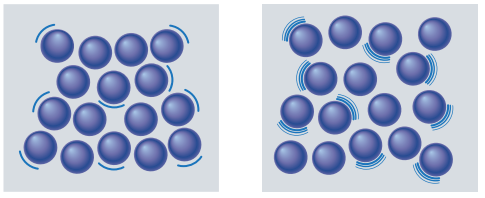


Figure 4 In a hot liquid, the particles jostle around faster and take up more space than in cold water.

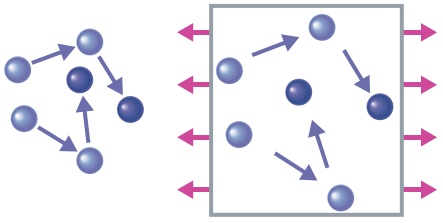


Figure 5 In a hot gas, the particles move faster, and collide with one another harder, than in a cold gas.

Heat causes expansion

All objects and substances expand (increase in size or volume) as their temperatures increase. These objects contract (shrink) back to their original size when they are cooled back to their original temperature. The expansion is only small – approximately 10 millimetres in a 30 metre bridge – but it is very important for the strength of the object. Expansion effects are seen in bridges, railway tracks and large buildings.

Applying heat energy causes the particles in the liquid or gas to gain more energy. The particles jostle more and speed up. As they move around faster, they take up more space and push the other particles further apart.

Expansion and contraction have many important applications such as liquid-in-glass thermometers. When an alcohol thermometer is placed in your mouth, the heat from your body passes to the liquid inside the thermometer, causing it to expand and move up the tube. Thermometers are filled with red- or green-coloured alcohol, but not the type of alcohol in alcoholic drinks.



Figure 6 Diffusion occurs faster in hot water (right) than in cold water (left).



Figure 7 Train tracks would buckle in the heat without tiny gaps between them.

Check your learning 15.6

Recall and explain

1 **Describe** what happens to particles when they are heated.

2 **Construct** a diagram similar to that shown in Figure 8. Add labels to show the energy changes between states.

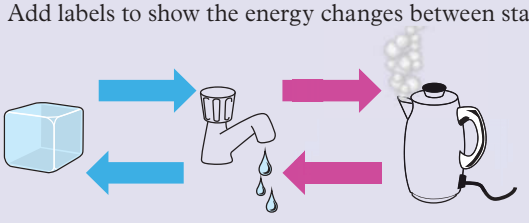


Figure 8 How energy changes between states

3 When hot objects cool, do they return to their original lengths? **Explain**.

Apply and analyse

4 **Contrast** the terms 'expand' and 'contract'.

5 What precautions are taken with railway tracks and bridges to ensure that they do not buckle and bend on a hot day? **Explain** why this is done.

6 How can you be sure that when a solid is heated and expands in size, the increase in size is not caused by more atoms being added?

7 **Contrast** the process of solidification and freezing.

Evaluate and create

8 **Suggest** how a thermometer determines difference in temperature.

Skills builder: Planning investigations

9 Decide what equipment you would use to measure the temperature of water that is being heated.

a **Identify** each piece of equipment you would use and how. (THINK: Imagine the method you would use step by step. What do you need at each step to measure the temperature of water safely?)

b What hazards do you need to be aware of to conduct the investigation safely? (THINK: What are the dangers of conducting this experiment, and how could you use equipment to prepare for these?)

REVIEW

Multiple choice

1 **Identify** what happens to water during condensation.
- **A** The solid melts into liquid.
- **B** The liquid heats to become a gas.
- **C** The liquid loses heat to become a solid.
- **D** The gas loses heat to become a liquid.

2 **Identify** what would happen to the particles in a beaker of water as it is heated.
- **A** The particles start moving faster.
- **B** The particles start moving slower.
- **C** The particles stop moving.
- **D** The particles start to disappear.

3 **Identify** the best description for 'density'.
- **A** The ability of a substance to scratch another substance
- **B** The ability of a substance to be compressed
- **C** The mass of a certain volume of a substance
- **D** The thickness of a liquid substance

Recall and explain

4 **Identify** the three most common states of matter.

5 **Identify** one word to replace each phrase.
- **a** The spreading out of a substance, such as a dye or smell
- **b** The ability of one substance to scratch another substance
- **c** The ratio of the mass divided by the volume

6 In which of the three major states of matter do the particles have the most energy? **Explain** your reasoning.

7 **Explain** density in terms of the particle model.

8 **Describe** how changing the energy of particles affects how they move in a container.

9 **Describe** the process of diffusion.

10 **Recall** what is meant by the term 'compressability'.

11 Use the particle model to **explain** the difference between solids, liquids and gases.

12 **Explain** the changes in particle movement as a substance changes state from solid – liquid – gas – liquid – solid.

Apply and analyse

13 **Contrast** the physical and chemical properties of a substance.

14 **Contrast** mass and matter.

15 **Explain** how a thermometer determines difference in temperature.

16 When you are boiling water, the volume of the water is reduced as it evaporates. Does this mean that the density of water changes? **Explain** your reasoning.

17 **Apply** the kinetic theory of matter to **explain** why the pressure inside car tyres will increase on a hot day.



Figure 1 Exhaling clouds!

18 When you breathe out on a cold morning, your breath appears white and foggy. This only occurs when it is very cold. What is the white fog that you see?Figure 1 Exhaling clouds!

19 A piece of wood has the density of 0.3 g/cm^3. If it takes up 60 cm^3 of space, **calculate** its mass.

Evaluate and create

20 Many people have ideas they think will explain observations and events in science. For an idea to become a theory, sit must be able to explain a range of observations. The idea must also be supported by evidence and/or observations.
- **a** **Identify** what evidence would have been required to support the idea that all substances are made of atoms.
- **b** It is found that a substance cannot be broken down into a more simple substance. How could you use the kinetic theory of matter to explain this observation? **Justify** your response.

21 Design a way to draw or model the following.
- **a** The melting point of a material
- **b** The boiling point of a material
- **c** The density of a material
- **d** The kinetic energy of a particle as it heats up





Figure 2 a The boiling point of water **b** the melting point of ice

22 **Investigate** expansion joints in suspension bridges (like the one in Figure 3). What purpose do they serve? Use the particle model to **describe** the importance of expansion joints for a suspension bridge on a hot day.



Figure 3 An expansion joint in a suspension bridge

Critical thinking

23 Go to your local grocery store (or you can even look around your home!) and **identify** 20 different grocery items, such as eggs, milk, ham, soft drink, fly spray and shampoo. Imagine that your grocery store is only going to have three aisles – Solids, Liquids and Gases. Using your knowledge of these three states of matter, **classify** them to organise the items into these three aisles only!

Going further

24 You should now realise that the structure and properties of a substance can be explained by the particles that make up the substance. **Explain** the following observations by referring to the arrangement and/or the movement of the particles within the substance. You can use labelled diagrams to improve your answers.

- **a** Water left in an open bottle will gradually evaporate and, if the temperature of the water increases, the water will evaporate more quickly.
- **b** Mercury is a unique substance because it is the only metal that is liquid at room temperature, and it even gives off a vapour (which makes it very dangerous because this vapour can be breathed into our lungs).
- **c** When you heat a piece of polythene it will melt. While it is liquid, it can be formed into a different shape; when it cools the polythene will stay in this new shape.
- **d** We can see steam, but we cannot see water vapour.

25 Polythene can be produced in two different forms: high-density polythene (HDPE) or low-density polythene (LDPE). If the particles in HDPE and LDPE are the same, **suggest** how the structures of the two substances would be different.

26 Design an experiment to determine how viscous 10 different household liquids (such as tomato sauce, shampoo and orange juice) are. Why do you think they are different? Offer an explanation for your most and least viscous liquids.



Figure 4 Melted chocolate is a liquid.

Research

27 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

»State of matter

The changes between the states of matter have many uses. Research some of these uses and their impact on our society. Some ideas are:

- how refrigeration and air conditioning work
- making moulds and casts, such as chocolate, iron and aluminium castings
- obtaining medical-grade oxygen and nitrogen from the air
- how the energy changes that occur during evaporation of water and the subsequent condensation of water vapour into rain affect thunderstorms and cyclones.

»People matter

The discovery of air pressure is a long and interesting story. Research the background of Evangelista Torricelli, Blaise Pascal and Otto von Guericke. For example, Otto von Guericke built a large water thermometer in the front of his house and made the Magdeburg hemispheres. Two opposing teams of eight horses, working like a tug-of-war, could not pull the hemispheres apart.



Figure 5 A chocolate mold

Reflect

Now that you've completed this chapter, reflect on your ability to do the following:

	I can do this.	I can't do this yet.	
Describe the behaviour of matter in terms of particles that are continuously moving and interacting.	☐	☐	Go to page 276–277.
Relate an increase or decrease in the amount of heat energy possessed by particles to changes in particle movement.	☐	☐	Go to page 282–283.
Use a simple particle model to predict the effect of adding or removing heat on different states of matter.	☐	☐	Go to page 282–283.
Relate changes in the physical properties of matter to heat energy and particle movement that occur during observations of evaporation, condensation, boiling, melting and freezing.	☐	☐	Go to page 270–273 and 282–283.
Explain density in terms of a simple particle model.	☐	☐	Go to page 280–281.
Identify the benefits and limitations of using models to explain the properties of solids, liquids and gases.	☐	☐	Go to page 274–275.

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ELEMENTS AND COMPOUNDS

What are the differences between elements and compounds?

16

Have you ever wondered ...

- Is there anything smaller than an atom?
- How did people in the past make utensils and tools without the technology that exists today?
- How do scientists around the world communicate with one another about the same chemicals when they speak a different languages?

SCIENCE UNDERSTANDING

In this chapter you will learn how to:

- describe the properties and uses of some common elements, including metals and non-metals
- identify how our understanding of the structure and properties of elements has changed as a result of some technological devices
- identify some examples of common compounds
- explain why internationally recognised symbols are used for common elements
- describe at a particle level the difference between elements, compounds and mixtures, including the type and arrangement of particles
- investigate how people in different cultures in the past have applied their knowledge of the properties of elements and compounds to their use in everyday life, e.g. utensils, weapons and tools.

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Check your Student obook assess for these digital resources and more:

QuizletLive
Compete in teams to test your knowledge.

Assess quiz
Before you start this chapter, assess your science skills.

Check your Teacher obook assess for these digital resources and more:

QuizletLive
Launch a quiz for your students on key concepts in this chapter.

16.1* Atoms make up matter

In this topic you will learn that:

- atoms are made up of protons, neutrons and electrons.

Video
Atomic structure

Scientists have studied atoms for centuries. The ancient Greeks used the word *atomos* to describe particles that could not be divided up any further. The concept of the atom was also referred to in ancient Indian texts. John Dalton and other chemists in the 17th century onwards further developed the idea, using the term 'atom' to describe those particles that couldn't be broken down any further by chemical means.

The particle model

In chapter 15, we explored the particle model, which was originally proposed by Dalton. To recap, this model states that:

- All matter consists of tiny particles called atoms.
- Atoms cannot be created or destroyed, and are indivisible.
- All atoms of the same element are identical, but different from atoms of other elements.
- Particles are too small to be seen.
- Particles are always moving. When it is hotter, the particles move faster; when it is cooler, the particles move slower.
- Particles have mass.
- Particles can join to make larger particles. When they combine, their masses add together.
- There are spaces between particles.
- Forces hold particles together to stop them from separating.



Figure 1 John Dalton

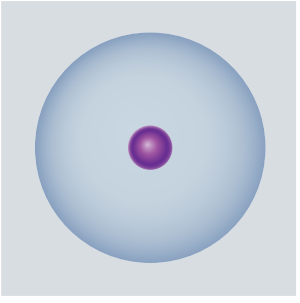


Figure 2 A basic representation of an atom's nucleus

What is an atom?

Throughout history, scientists have proposed different models of how atoms are structured. As scientific discoveries and technology advanced, we know more and more about these tiny particles we cannot see.

Today, we know that atoms are made up of subatomic particles called protons, neutrons and electrons. The protons and neutrons of an atom are located within the nucleus. These subatomic particles are responsible for most of the mass of the atom and therefore have a strong influence on the properties of the atom. Electrons orbit the nucleus in shells and can interact with other atoms.

The smallest atom in terms of mass is the hydrogen atom. Next is helium. Heavier atoms include those of lead and uranium.

Our understanding of the atom has changed

As our scientific understanding increases over time, so does our understanding of atoms. One of the earliest views of the atom was proposed by Greek philosopher Democritus in 442 BCE. He believed that matter was made of tiny particles that could not be divided.

In 1803, English chemist John Dalton proposed his own 'atomic theory', in which he described matter as tiny indivisible particles called atoms. He proposed that all the atoms of a specific element would have the same properties and mass. Dalton conducted many experiments with gases, trying to identify what particles they were made from.

But in 1897, British physicist JJ Thomson (1856–1940) discovered that atoms were not 'indivisible' as Democritus and Dalton first thought. All atoms contain negative particles, otherwise known as electrons. In 1904 Thomson suggested a model that atoms were organised like a plum pudding – the electrons were scattered through a solid positive atom, like fruit is scattered through a solid pudding.

In 1911, New Zealand-born English physicist Ernest Rutherford (1871–1937) discovered that every atom has a nucleus. Through his gold foil experiment, he proved that atoms were not solid and in fact contained a lot of space. He did this by shooting a beam of alpha particles at the gold foil. If the gold atoms were solid, the beam wouldn't pass through. But alpha particles did pass

through, which meant the atoms were not solid. Rutherford's model suggested that the protons were located in the middle of an atom, surrounded by mostly empty space, where electrons moved around in orbits. Because this model resembles how planets move around the Sun, it is sometimes called the planetary model of the atom.

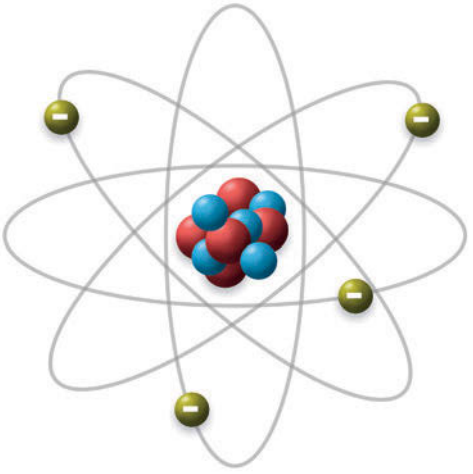


Figure 3 Ernest Rutherford found that every atom contained a nucleus.

In 1922, Danish physicist Niels Bohr (1885–1962) developed a theory that is still somewhat used today. The Bohr model explains that electrons orbit an atom's nucleus in specific 'shells'. Bohr proposed that electrons can jump between these shells and when they do, they emit a photon at an exact wavelength.

As technology advanced further, British physicist James Chadwick (1891–1974) discovered the neutron in 1932. He did this by firing alpha rays (which are positively charged) at some beryllium, which then emitted a neutral charged ray. This meant Bohr's model needed to be adjusted; it became the Chadwick–Bohr Model.

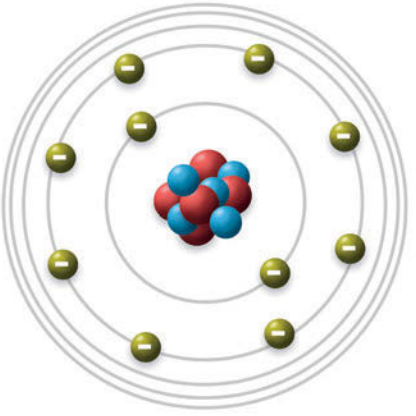


Figure 4 Niels Bohr proposed that an atom's electrons orbited in 'shells'.

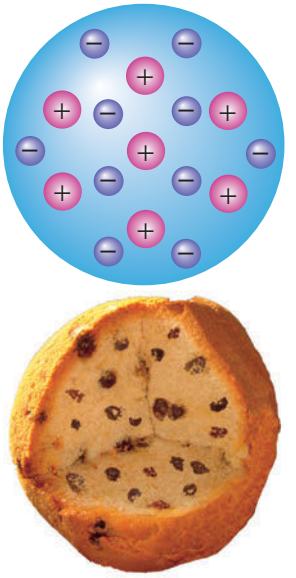


Figure 5 JJ Thomson thought that atoms were structured like a plum pudding (bottom).

Interactive
The atom

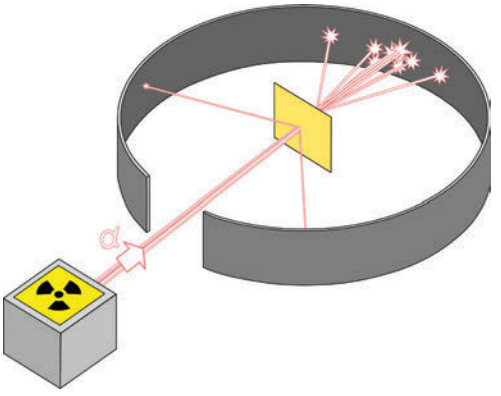


Figure 6 Ernst Rutherford's gold foil experiment proved that atoms were not solid because a beam of alpha particles could pass through gold atoms.

Check your learning 16.1

Recall and explain

1 **Identify** the three subatomic particles that make up an atom.

2 **Describe** the structure of an atom.

Apply and analyse

3 Democritus believed that atoms were solid particles that could not be divided into smaller units. **Explain** how he was wrong.

4 **Construct** your own diagram to show the structure of an atom. Use labels to **explain** what you have drawn.

Evaluate and create

5 Using the information in this topic, **construct** a timeline to show how our understanding of the atom has developed.

Skills builder: Questioning and predicting

6 Write two of your own scientific questions about atoms. (THINK: What would you like to know more about?)

16.2 Elements are organised by their properties

In this topic you will learn that:

- an element is a pure substance made of only one type of atom
- elements are represented using internationally recognised symbols
- elements are organised by their properties on the periodic table.

What is an element?

element
a pure substance made of only one type of atom

An **element** is a pure substance made of only one type of atom. All the atoms in the element are identical. For example, gold is an element that is made up of only gold atoms. The properties of an element are determined by the number of electrons in the atom's shell.

There are 90 different elements that are found naturally on Earth. Each element is made of a different type of atom. Another 20 or so atoms have been made artificially, but these are highly radioactive. These artificially made atoms are too large to be stable and disintegrate almost as soon as they are made.

Elements cannot be broken down into other substances because they are already the simplest substances. They can be thought of as being 'elementary', which is the origin of the name element.

The element is the substance that can be observed and has properties that can be measured. Atoms are far too small to be observed and are incredibly difficult to measure.

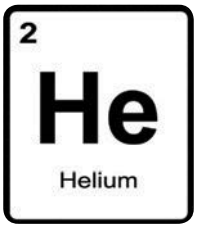


Figure 1 Letter symbols are used to represent elements.

Using universal symbols

periodic table
a table that arranges all the elements in order of the number of protons that the atom has in its nucleus

atomic number
the number of protons of an atom

period
a horizontal list of elements found on the periodic table

group
a vertical list of elements found in the periodic table that have characteristics in common

You will notice that elements are represented by their symbols, which consist of one or two letters: hydrogen has the symbol 'H'; helium has the symbol 'He'. Other elements (and their symbols) are oxygen (O), carbon (C), nitrogen (N), sulfur (S), gold (Au) and silver (Ag).

In 1828, Swedish scientist Jöns Jakob Berzelius (1779–1848) introduced letters as a way of simplifying the way we represent elements. Berzelius chose the first letter of the Latin name for each element. Some symbols make more sense to us in English, such as O for oxygen. But Ag comes from the Latin word *argentum* for silver; and gold is *aurum* in Latin, therefore having the symbol Au.

If elements started with the same letter, subsequent letters (in lowercase) was used. For example, carbon is C and copper is Cu, which has the Latin name *cuprum*.

This same set of chemical symbols is recognised and used around the world, making it easier for scientists to communicate their ideas across languages. For example, imagine a group of scientists trying to research and share their findings about silver (Ag) if they are all using a different word to describe it. By using the same shared symbols, scientists can collaborate with one another around the world.

Table 1 The word 'silver' written in different languages

French	Argent
English	Silver
Mandarin	銀
Arabic	ةضف

Arranging elements on the periodic table

The **periodic table** arranges all the elements in order of the number of protons that the atom has in its nucleus. Each atom has a unique number of protons – that is, it is the number of protons an atom has that makes it that particular atom. The number of protons in an atom is called the **atomic number**. For example, lithium has the atomic number of 3; therefore, it has 3 protons.

The horizontal rows in the periodic table are called **periods**. The vertical columns are called **groups**, which are numbered 1–18.

The elements in a group often have similar properties, such as the way they look or how they behave.

CHALLENGE **16.2A:** Classifying elements Go to your obook.

CHALLENGE **16.2B:** Identifying the elements in the periodic table Go to page 400.

INVESTIGATION **16.2:** Properties of the elements Go to page 400.

In the solid state, atoms of metals are held in a lattice. Most other elements, which are not metals, are called non-metals. Most non-metals are gases at normal temperatures. Some gases, such as neon and helium, are **monatomic**. This means that each gas particle is a single atom (*mono* means 'one').

monatomic molecule
a molecule that consists of one atom

Interactive
Navigating the periodic table

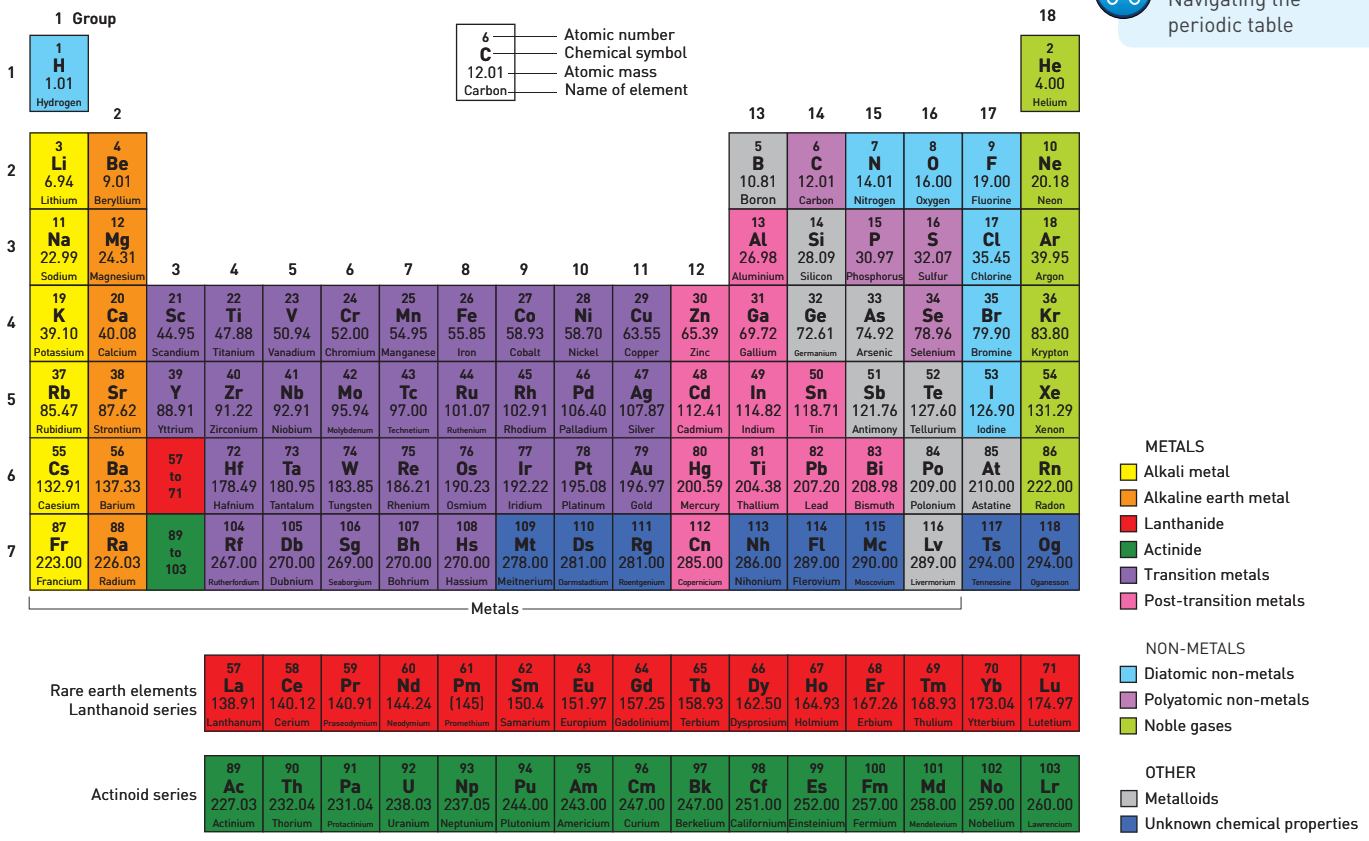


Figure 2 The periodic table

Check your learning 16.2

Recall and explain

1 **Recall** the connection between atoms and elements.

2 What is a chemical symbol?

3 **Recall** the name for the rows of the periodic table.

4 **Identify** which element is in period 3, group 2.

Apply and analyse

5 Use the periodic table to complete the following table.

Element	Atomic number
Beryllium	
	9
Magnesium	
	11

Evaluate and create

6 **Propose** a reason to explain why no two elements can have the same chemical symbol.

7 **Investigate** one element. Use the internet to find out:

- its symbol
- where it got its name from (is it English or Latin?)
- whether it is a metal or non-metal
- what kinds of properties it has
- what it can be used for.

Skills builder: Communicating

8 **Explain** why internationally recognised symbols are used for common elements. (THINK: How will you describe this concept clearly?)

16.3 Groups in the periodic table have properties in common

In this topic you will learn that:

- the two main types of elements are metals and non-metals
- common properties of metals include being lustrous, able to conduct heat and electricity, malleable and ductile
- non-metals do not have the properties common to metals.

metal
a collection of elements found on the left-hand side of the periodic table that are malleable, lustrous, ductile and highly conducting

metalloid
a small collection of elements that have a mixture of characteristics of metals and non-metals

Metals

Nearly three-quarters of all elements are metals. **Metals** are defined by their lustrous appearance and their ability to conduct heat and electricity.

Metals have many properties in common. Pure metals are:

- lustrous (shiny)
- able to conduct heat and electricity
- malleable (able to be beaten into a new shape)
- ductile (able to be drawn into a wire).

Metals are very reactive and can react with oxygen, water and acids. There are different groups of metals – alkali metals, alkaline earth metals, transition metals, actinides and lanthanides. Typically, as you move down a group of metals in the periodic table, they become more reactive. Metals are solid at room temperature (with the exception of mercury) and when they are a flattened into a thin sheet, they are opaque (cannot see through them).

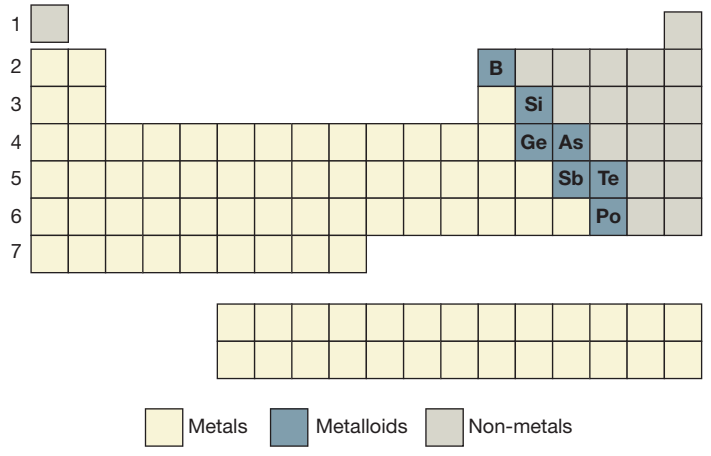


Figure 1 Regions of the periodic table

Metalloids

Metalloids are the small set of elements along the 'staircase' diagonal boundary between the metals and non-metals (see Figure 1). As might be expected from this location, metalloids exhibit properties between those of metals and non-metals. Most of their properties would be considered 'un-metallic'; however, metalloids conduct electricity like the metals.



Figure 2 Not all metals are the same.



Figure 3 Silicon and germanium are widely used in electronic devices because of their semiconductor properties – they conduct electricity in a very controlled way.

Non-metals

Non-metals, as the name suggests, are elements that do not have the set of properties common to all metals. None are lustrous (shiny), and none are ductile (easily manipulated); however, a small number of non-metals are coloured and some are brittle. In addition, non-metals have a much larger range of melting points and boiling points than the metals do. At room temperature, several non-metals are gases and one (bromine) is a liquid, whereas all the metals except for one (mercury) are solids at room temperature.

The noble gases

The **noble gases** are found in group 18. The noble gases are so called because they are all gases at room temperature and are unchanged if mixed with other elements. They are colourless, odourless and nonflammable, and include:

- helium (He)
- neon (Ne)
- argon (Ar)
- krypton (Kr)
- xenon (Xe)
- radon (Rn)
- oganesseon (og).

Common elements used today

Today we are able to harness the properties of different elements. We can also use elements in different ways if they come in different forms. These different forms of the same element are known as allotropes. For example, carbon can come in the form of graphite (which is very soft) or diamond (which is the hardest substance on Earth). In fact, diamond is so hard that it is often used to coat cutting tools such as saws. Table 1 outlines some other uses of common elements.

non-metal
a collection of elements that are found on the right-hand side of the periodic table

noble gas
a collection of gaseous elements found in group 18 of the periodic table

Table 1 Common elements and their uses

Element	Metal/ non-metal	Chemical symbol	Atomic number	Uses
Carbon	Non-metal	C	6	• Coal for fuel • Diamond jewellery • Graphite pencils
Aluminium	Metal	Al	13	• Foil • Kitchen utensils • Aeroplane parts
Sulfur	Non-metal	S	16	• Matches • Fireworks • Insecticide

Check your learning 16.3

Recall and explain

1 **Recall** the dominant state of matter within the groups of non-metals.
2 **Identify** the properties of non-metals.
3 **Identify** what proportion of the periodic table is composed of metals.

Apply and analyse

4 **Examine** the periodic table on page 291.
   a **Identify** the period and group for each of the following elements: fluorine, bromine, tin, radium, potassium, platinum, arsenic.
   b Are any of the elements in part (a) in the same group? What would this tell you about them?
   c Are any of the elements listed in part (a) in the same period? What would this tell you about them?

Evaluate and create

5 Design a way to represent the different groups of metals clearly and informatively, **identifying** the distinguishing properties of each group.
6 Why could the term 'metal-like' be used to describe metalloid elements? **Suggest** a better name for this group of elements. **Justify** your answer.

Skills builder: Planning investigations

7 Hera found three unlabelled jars, each containing one element. She wrote down some observations about each.
   a **Identify** whether you think it is a metal, non-metal or metalloid.
   a **Identify** a test for each substance that could confirm your prediction. (THINK: What do you know about the properties of metals and non-metals that could help you to devise a test?)

Observations	Metal, non-metal or metalloid?	Test
Shiny metal on the outside and soft		
Brown liquid		
Shiny, brittle solid		

16.4 Our understanding of elements is developing over time

In this topic you will learn that:

- our understanding of elements and their properties has developed as technology has advanced.

The development of the periodic table involves scientists building on the work of previous generations. The discovery of new elements and the ability to recognise patterns and predict the existence of previously unknown elements all result from scientists analysing and refining models and technologies.

The creation of the periodic table is often credited to Russian chemist Dimitri Mendeleev (1834–1907), who constructed a table with gaps for yet-to-be-discovered elements; however, the ideas he used continue to be refined as technology progresses.

Since elements were first studied by the ancient Greeks, our understanding of matter continues to evolve.

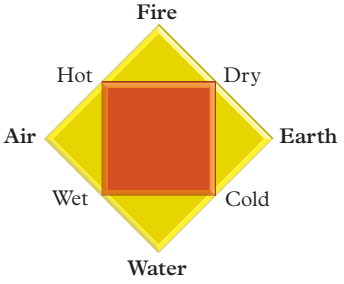


Figure 1 The four Greek 'elements'

2000 years ago
The ancient Greeks thought that everything was made of four 'elements' mixed together in different ratios.

1661
Irish-born chemist Robert Boyle suggested that an element was a substance that cannot be broken down into a simpler substance in a chemical reaction.



Figure 2 Robert Boyle





Figure 3 Antoine Lavoisier and Marie-Anne Lavoisier

1789
Antoine Lavoisier, a French nobleman, made a detailed list of the substances that he believed to be elements. Assisted by chemist Marie-Anne Paulze Lavoisier, Lavoisier list contained 33 elements grouped into metals and non-metals, as well as some substances that we now know to be compounds. Lavoisier conducted many experiments where he combusted substances in air and the resulting substances increased in mass.

1894
William Ramsay, a Scottish chemist, used the then new technology of refrigeration to liquefy and separate the components of air. He successfully removed water, carbon dioxide, oxygen and nitrogen, but found he had some unknown gas leftbehind. This was argon, the first inits group to be discovered. Further experimentation identified helium,neon, krypton and xenon. All these gases form the group of noble gases at the far right of the periodic table.

Check your learning 16.4

Recall and explain

1 **Recall** how one technological advance helped a scientist to further their understanding of elements.

Apply and analyse

2 **Account** for why the gases discovered by Ramsay were not discovered earlier.

3 Using the timeline, **assess** how our understanding of elements has changed due to advances in technology.

Evaluate and create

4 In recent history many synthetic elements have been discovered.
   - **a** Name one synthetic element.
   - **b** **Identify** its atomic number and place in the periodic table.
   - **c** **Describe** how it was discovered.
   - **d** **Evaluate** the role technology may have played in its discovery.

5 Create a pamphlet that includes the information found above.

Skills builder: Processing and analysing information

6 Using the timeline, **construct** a table that organises this information to show the discoveries aided by each piece of technology. (THINK: What will you label your columns? What is the title for the table?)

1869
Dimitri Mendelev created the first periodic table, leaving empty spaces on the table for elements that were yet to be discovered. He did this by investigating the known physical and chemical properties of elements and noticing recurring properties between them. Building on the ideas of his contemporaries, Mendeleev, who lived in Russia, knew of 63 elements.

1900



Figure 4 Marie Curie

1911
Marie Curie was one of the many female scientists who identified and purified elements of the periodic table. She discovered both radium and polonium. Curie won two Nobel Prizes for her work on radiation.

1913
By the early 1900s, X-rays could be used to determine the atomic number of each element. Using this technology, Henry Moseley, a young English physicist, refined the order of some of the elements in Mendeleev's periodic table and proposed a minor change to the periodic law: elements have properties that recur or repeat according to their atomic number.



Figure 5 Henry Moseley

1940
With the development of nuclear processes, elements heavier than uranium could be created. US scientist Glen Seaborg, winner of the 1951 Nobel Prize in Chemistry, led a team of scientists who used a cyclotron to slam neutrons into uranium atoms. This created the very first atoms of neptunium and plutonium.

1981
Gerd Binnig and Heinrich Rohrer invent the scanning tunnelling microscope.This microscope could see individual atoms.

Today

Today
Since the 1940s, similar nuclear processes have been used to synthesise the elements up to and including element 118.

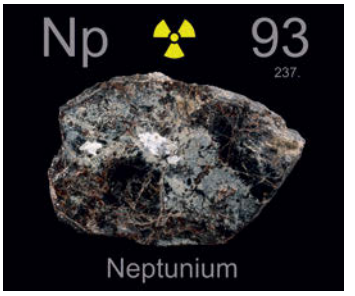


Figure 6 Atoms heavier than uranium are called the 'transuranium' or 'transuranic' elements. None of these occurs naturally. The image shows a sample of neptunium.

16.5 Atoms bond together to make molecules and compounds

In this topic you will learn that:

- molecules are groups of two or more atoms that are bonded together; they can be the same element or different
- when a molecule is made up of different elements, it can also be called a compound.

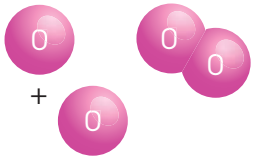


Figure 1 An oxygen molecule (O_2) is formed by two oxygen atoms.



Figure 2 A carbon dioxide molecule (CO_2) is a compound made up of one carbon atom and two oxygen atoms.

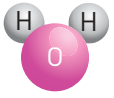


Figure 3 A water molecule (H_2O) is a compound made up of two hydrogen atoms and one oxygen atom.

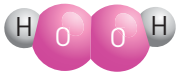


Figure 4 A hydrogen peroxide (H_2O_2) molecule is a compound made up of two hydrogen atoms and two oxygen atoms.



Figure 5 A carbon monoxide (CO) molecule is a compound made up of one carbon atom and one oxygen atom.

What are molecules?

Molecular substances can be elements (made of the same type of atoms), such as oxygen (O_2), or compounds (made of two or more different types of atoms bonded together), such as water (H_2O) and carbon dioxide (CO_2). We use a chemical formula to show the types and numbers of atoms that make up molecules.

Oxygen is an example of a **molecular element**. An oxygen molecule consists of two oxygen atoms joined together. Oxygen gas is a substance made of oxygen molecules. Pure oxygen gas consists of millions and millions of oxygen molecules, all exactly alike. This means that the word 'oxygen' can be used in two different ways: it can be used to describe the element, or it can be used as the name of the molecule. When you see the names of chemicals being used, check the way in which the name is being used.

Molecules of a compound contain atoms of two or more different elements that are chemically bonded together. Carbon dioxide is a **molecular compound**. Its molecules contain carbon and oxygen atoms. Pure carbon dioxide gas (the substance) consists of millions and millions of carbon dioxide molecules.

Water is another molecular compound. A water molecule consists of one atom of oxygen joined to two atoms of hydrogen. Pure water consists of many millions of water molecules. The water molecules are all identical.

Compounds and mixtures

You have seen that elements contain only one type of atom. However, you will know that there are far more substances than just the 90 naturally occurring elements.

Most of the substances we use are compounds. By altering the numbers and types of atoms, chemists can alter the properties of these substances. Many of the substances that are important to our society are used because of their important properties. These compounds are made in factories or obtained from natural products. Some important compounds are pharmaceuticals, fertilisers and polymers.

Compounds are very different from mixtures. A mixture is two or more substances that are physically combined. They are separated using physical separation techniques such as filtration, centrifuging and distillation. When separated, no new substances are made. For example, when separating sand from salt, you still have sand and salt,

In contrast, a compound is where two or more elements are chemically combined and cannot be separated using physical techniques. Some chemical techniques include reacting the compound with other substances, passing electricity through it and combusting the substance.

When separating a compound, such as water, it forms its elements of hydrogen and oxygen. This can be done by running electricity through the water. The apparatus used to do this is a called a Hoffman voltameter – the electricity splits the water molecule into hydrogen and oxygen.

Some compounds are molecular, such as water and carbon dioxide, whereas other compounds are called **polymers**. The molecules in polymers are made of groups of atoms that repeat over and over – like the

INVESTIGATION
16.5: Decomposing copper carbonate
Go to page **401**.

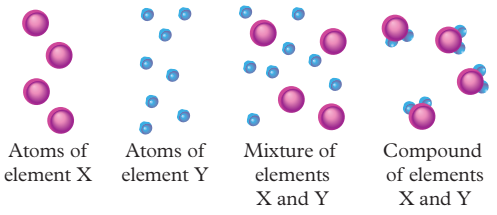


Figure 6 Mixtures are different from compounds.

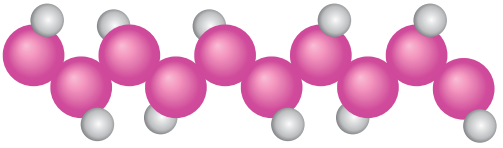


Figure 7 A polyethylene molecule is made up of thousands of carbon atoms joined in a chain, with hydrogen atoms attached to the carbon chain.

beads on a necklace. Plastics are examples of polymers. Other polymers include chemicals found in plants and animals like starch and proteins.

Other compounds, such as sodium chloride, do not contain molecules but exist in a lattice arrangement, with atoms held together in three-dimensional networks.

Elements and compounds are pure substances. The particles within one pure substance, whether they are atoms or molecules, are all the same. Figure 9 shows the different types of substances.

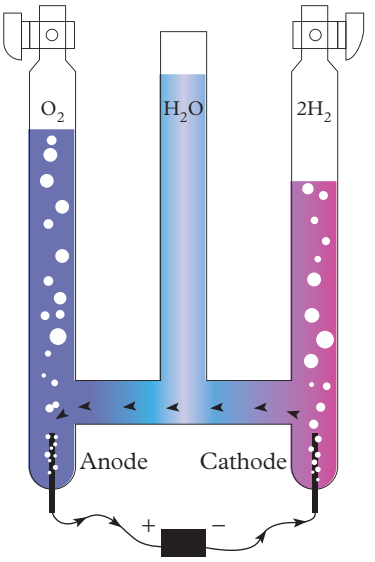


Figure 8 A Hoffmann voltameter passes electricity through water to separate it into its elements of hydrogen and oxygen.

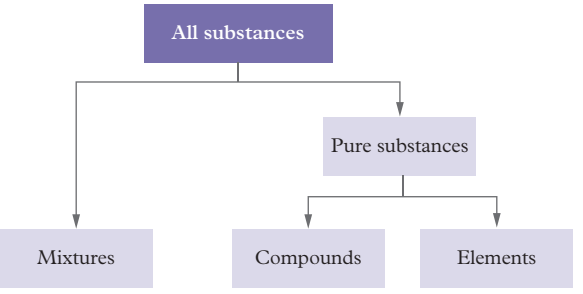


Figure 9 Different types of substances

molecular element
atoms of one element chemically bonded together

molecular compound
atoms of two or more different elements that are chemically bonded together

polymer
a chemical compound with molecules made of groups of atoms that repeat over and over

Interactive
Elements and compounds

Check your learning 16.5

Describe and explain

1 Look at the diagrams below in Figure 10, which show **a** a mixture of an element and a compound, **b** a mixture of two elements, and **c** a pure element. State which description matches which diagram, **explaining** your reasoning for each type of substance.

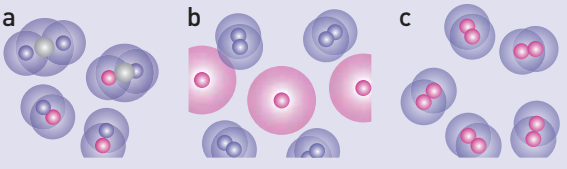


Figure 10 Compound or mixture?

2 What are some elements that exist as molecules rather than single atoms?

3 How are molecules and compounds related? **Explain** your answer.

4 **Distinguish** the meanings of the following groups of words.
- **a** Atoms and molecules
- **b** Elements and compounds
- **c** Diatomic and monatomic
- **d** Molecule, polymer and lattice

Skill builder: Problem solving

5 Robert Boyle claimed that an element was a substance that cannot be broken down into a simpler substance. **Evaluate** this claim.
(THINK: What do you know about elements and their structure? Use your scientific knowledge of elements to explain why he was correct or incorrect.)

16.6 Elements and compounds have been used throughout history

In this topic you will learn:

- how people from different cultures have applied the properties of elements and compounds to their use in everyday life.

First Australians use compounds

For thousands of years, Aboriginal and Torres Strait Islander peoples have used natural resources. Across Australia, different groups have used minerals and compounds in many ways. For example, the Wiradjeri people developed different stone tools that could be used for hunting and cooking. These could be made by hitting a piece of stone against another to remove stone fragments. Obsidian and quartz were effective to use as cutting edges. Both obsidian and quartz are compounds made up of silicon and oxygen in different amounts.

Aboriginal and Torres Strait Islander peoples across Australia also use ochre, which can be ground up into a paint.



Figure 1 Aboriginal and Torres Strait Islander peoples use ochre, clay and charcoal as a paint.

This paint is used in many different ways, including on the body. The ochre paintings that were created across thousands of years by the first Aboriginal and Torres Strait Islander peoples can still be seen today around Australia.

Ancient Egyptians used copper

The ancient Egyptians are known to have used copper for many different purposes. Because copper is malleable, it could be used to make tools such as hoes and sickles, or items for the home, such as dishes and knives.

As they learnt more about copper, the Egyptians began to use it for other purposes such as beauty. They made mirrors and razors out of copper, and made green and blue makeup from copper compounds such as azurite (see Figure 3).



Figure 2 Ku-ring-gai Chase National Park, NSW, is a good place to see how ochre is used. But remember not to touch! The acid on our skin can damage the ochre artwork.



Figure 3 The ancient Egyptians used azurite (a copper carbonate mineral) for blue makeup.

The ancient Egyptians were also one of the ancient civilisations to combine copper with tin or arsenic to create bronze. Bronze was a much harder substance than copper and could be used to make stronger, sharper weapons and tools (see Figure 4).

Ancient civilisations used gold to make coins

For thousands of years, gold has been used as a currency in many different civilisations. The first real gold coins were made around 600 BCE in Lydia (Western Turkey). The ancient Greeks and Romans also used coins to pay their armies, stamping the face of their leader on their coins (see Figure 6). Since then, gold coins have been used as currency in many other cultures, including in Australia today.

Gold was likely chosen to be used for coins for a number of reasons:

- It is rare enough to be valuable (but there is still enough to make the coins).
- It is malleable enough to shape into coins.
- It does not corrode over time.



Figure 4 The ancient Egyptians used bronze to cast stronger weapons.



Figure 5 This Egyptian statue of a cat is cast from bronze, with gold ornaments.



Figure 6 This Roman coin is stamped with the face of Emperor Nero.

Check your learning 16.6

Descibe and explain

1. **Describe** one way in which Aboriginal and Torres Strait Islander cultures use natural resources for everyday living.
2. **Recall** two reasons why gold has been used to make coins.
3. **Recall** two reasons why the ancient Egyptians used copper.

Evaluate and create

4. **Investigate** how one culture has used their knowledge of an element in everyday life. Present your findings to your class in a format of your choice.
5. **Investigate** one of the following elements or compounds to discover how it has been used throughout history: silver (Ag), tin (Sn) or chlorine (Cl).

Skills builder: Conducting investigations

6. Consider your investigation for questions 4 or 5 above. **Explain** how you identified the best information to use to answer the question.
   (THINK: How did you conduct your search for information? What criteria did you use when choosing which sources to trust and use?)

REVIEW

Multiple choice

1 What is an element?
- **A** A mixture of different types of atoms
- **B** A substance made up of one type of atom
- **C** A substance made up of two types of atoms that are chemically combined
- **D** The smallest particle that can exist

2 What is a common property of metals?
- **A** Liquid at room temperature
- **B** Lustrous
- **C** Does not conduct metals well
- **D** Non-malleable

3 Which of the following is an example of a compound?
- **A** Oxygen (O)
- **B** Carbon (C)
- **C** Chlorine (Cl)
- **D** Hydrogen peroxide (H_2O_2)

Recall and explain

4 **Describe** the structure of an atom.

5 **Explain** what the overall order of elements in the periodic table is based on.

6 **Describe** the difference between an element, a compound and a mixture. **Identify** the type and arrangement of particles in your answer.

7 **Recall** the name given to the following features of the periodic table.
- **a** Horizontal row
- **b** Vertical column

8 **Describe** the difference between a molecular compound and a molecular element.

9 Use the periodic table in the back of your book to complete the table below with either the symbol, the name of the element or the atomic number.

Symbol	Atomic number	Name of element
Hg		
		Oxygen
	24	
Na		
		Magnesium
	55	
		Manganese
Au		
	36	
Ag		

10 **Recall** the features that elements in the non-metals group have in common.

11 **Recall** the names of the different groups of metals that can be found in the periodic table.

12 **Describe** what special feature of metals allows them to conduct electricity in the solid state.

13 **Identify** whether the following substances are an element or a compound: water, iron, carbon dioxide, potassium, diamond.

14 Complete the table below, **identifying** whether the property is common for metals or non-metals.

	Metal or non-metal?
Conducts electricity	
Mostly a gas at room temperature	
Brittle	
Ductile	
Dull in appearance	

15 **Identify** the three subatomic particles in an atom. Where are each of these particles located?

16 **Recall** what properties are shared by all metallic elements.

Apply and analyse

17 If you heated a newly discovered substance and it decomposed into two new substances, was the original substance an element or a compound? Provide reasons your answer.

18 Only two elements are liquids at room temperature – bromine and mercury. Bromine is a non-metal and mercury is a metal. **Predict** how these two liquids are likely to appear and behave differently from each other.

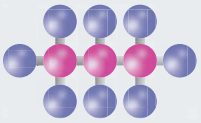
19 **Compare** the models of Bohr, Dalton, Rutherford, Democritus and Thompson.

20 A substance has two elements chemically bonded to each other. **Classify** it as a mixture or a compound.



Figure 1 Mercury is a liquid at room temperature.

21 Looking at each of the models in the table below, **identify** whether they represent an element, a compound or a mixture.

Model	Element, compound or mixture?
	
	
	
	
	
	

22 **Analyse** the following statement: 'The identity of an element can always be determined if the atomic number is known.' **Explain** the scientific reasoning that justifies it.

Evaluate and create

23 Elements only contain one type of atom, whereas compounds contain a combination of different atoms. This difference in structure can explain some of the behaviours of elements and compounds. By referring to the arrangement of atoms, **explain** the following statements.

- **a** When an electric current is passed through water, it is possible to produce hydrogen gas and oxygen gas.
- **b** Early chemists, called alchemists, tried to turn lead and other metals into gold, but none of them succeeded.
- **c** When limestone, which is made of the compound calcium carbonate ($CaCO_3$), is heated strongly, carbon dioxide gas is produced. However, when iron is heated, no new substance is created.

24 Scientists such as Berzelius and Mendeleev worked on their own to produce new ideas. Others, like Seaborg, worked in a team. Now most scientists work in teams. What are the advantages of working in a team?

25 **Investigate** one non-metal and develop a presentation or poster that communicates how it is used by society.

26 Meyer and Mendeleev each published a periodic table within months of each other. However, Mendeleev is given sole credit for developing the periodic table.

Is it fair that the person who first discovers, develops or publishes something receives the credit for this discovery? **Justify** your response.

Critically thinking

27 Consider the balls or circles we use to represent particles when we model compounds and molecules. Is this a good way to model molecules and compounds? **Justify** your response.

Going further

28 A student claimed that sodium chloride is made of molecules. Is the student correct? **Investigate** the compound and **discuss** the student's claim.

29 A substance will conduct electricity if it contains charged particles that are free to move across the sample. The charged particles can be electrons or ions. **Discuss** why ionic compounds cannot conduct electricity when in the solid state but can conduct electricity when melted.

30 Scientists have had to deduce what it is like inside an atom from indirect evidence, similar to how astronomers determine the temperature and composition of stars. **Evaluate** the advantages and disadvantages of using indirect evidence to develop scientific theories.

Research

31 Choose one of the following topics on which to conduct further research. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your findings in a format that best fits the information you have found and understandings you have formed.

»The noble gases

The story behind the discovery of the noble gases is a fascinating one. The challenge was this: how do you detect the existence of something that only exists as a gas that does not react with anything and, except for argon, is only present in the air in extremely small concentrations? How was the first noble gas found? What role did the periodic table of that time play in helping chemists hunt for other noble gases?

»Hydrogen

Hydrogen is a most unusual non-metal because it can form H^+ ions and H^- ions depending on what it reacts with. Although alkali metals do not react with one another, hydrogen will react with alkali metals and form compounds, such as lithium hydride (LiH). Show why the hydride ion (H^-) is stable. What are the properties of metal hydrides such as lithium hydride? What uses are made of these compounds?



Figure 2 Model of the hydrogen molecule

Reflect

Now that you've completed this chapter, reflect on your ability to do the following:

	I can do this.	I can't do this yet.
Describe the properties and uses of some common elements, including metals and non-metals.	☐	☐ Go to page 292–293.
Identify how our understanding of the structure and properties of elements has changed as a result of some technological devices.	☐	☐ Go to page 294–295.
Identify some examples of common compounds.	☐	☐ Go to page 296–297.
Explain why internationally recognised symbols are used for common elements.	☐	☐ Go to page 290–291.
Describe at a particle level the difference between elements, compounds and mixtures, including the type and arrangement of particles.	☐	☐ Go to page 296–297.
Investigate how people in different cultures in the past have applied their knowledge of the properties of elements and compounds to their use in everyday life, e.g. utensils, weapons and tools.	☐	☐ Go to page 298–299.

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MIXTURES

What happens when substances physically combine and how can they be separated again?

17

Have you ever wondered ...

- What is fog?
- Why does more chocolate dissolve in hot milk compared with cold milk?
- Why is water from the tap safe to drink?

SCIENCE UNDERSTANDING

In this chapter you will learn how to:

- describe the importance of water as a solvent in daily life, industries and the environment
- describe aqueous mixtures in terms of solute, solvent and solution
- relate a range of techniques used to separate the components of some common mixtures to the physical principles involved in each process, including filtration, decantation, evaporation, crystallisation, chromatography and distillation
- investigate the application of a physical separation technique used in everyday situations or industrial processes, e.g. water filtering, sorting waste materials, extracting pigments or oils from plants, separating blood products or cleaning up oil spills
- research how people in different occupations use understanding and skills from across the disciplines of Science in carrying out separation techniques.

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Check your Student obook assess for these digital resources and more:

QuizletLive
Compete in teams to test your knowledge.

Assess quiz
Before you start this chapter, assess your science skills.

Check your Teacher obook assess for these digital resources and more:

QuizletLive
Launch a quiz for your students on key concepts in this chapter.

17.1 Mixtures are a combination of two or more substances

In this topic you will learn that:

- mixtures are made up of two or more substances
- pure substances are made up of one substance.

mixture
something made up of two or more pure substances mixed together

substance
a solid or liquid that can be mixed

pure substance
something that only contains one type of substance

solution
a liquid made up of a solvent with a solute dissolved in it

suspension
a cloudy liquid that contains insoluble particles

sediment
something that settles to the bottom in a mixture

colloid
a type of mixture that always looks cloudy because clumps of insoluble particles remain suspended throughout it – they don't settle as sediment

Consider the things around you. Perhaps they are made of wood, glass or plastic. Wood, glass and plastic are all **mixtures** because they are made up of two or more **substances**. Some materials are pure substances. A **pure substance** is one that is not combined with anything else. Pure water, oxygen and diamonds are examples of pure substances.

Properties of mixtures

There are many different types of mixtures, each with different characteristics. For this reason, scientists have grouped mixtures according to their properties: what they are made of and how they behave. Knowing the type of mixture helps us work out ways to separate it into pure substances.

Solutions

When you mix salt into water, it seems to disappear. But we know the salt is still there because we can taste it. The particles of salt become so small that they spread evenly throughout the water. This clear mixture of salt and water will not separate by itself. It is a solution. A **solution** is a mixture where one substance (a solute) is dissolved evenly throughout another (a solvent). Solutions are usually transparent (or see-through).

Suspensions

Dirty water is an example of a suspension. A **suspension** is a mixture of two substances, where a solid is dispersed, undissolved, in a liquid. The result is a cloudy liquid. Sand in water is another example of a suspension. If you shake a container of sand and water, the sand will spread through the water, forming a cloudy liquid. The sand will then settle to the bottom of the container as **sediment**. Suspensions will often need to be shaken or stirred before use to spread the solid bits of sediment through the liquid again.

Colloids

When two or more substances are mixed, they don't always separate out with time. Suspensions that don't separate easily are referred to as **colloids**. These can be formed by a solid being suspended in a liquid, such as hot chocolate in milk. Occasionally different particles can get suspended in a gas. Fog is an example of this: small drops of water suspended in the air. The word 'colloid' comes from the Greek *kolla*, which means 'glue'. You can think of a colloid as a substance being 'stuck' – suspended in another substance. The benefit of colloids is that there is no need to mix them before using them. Hair gel and hand cream are examples of colloids.



Figure 1 Most of the things we use every day are mixtures. What mixtures can you see in this photograph? Can you see any pure substances?

CHALLENGE
17.1: Comparing different types of mixtures
Go to page **402**.

Emulsions

An **emulsion** is a colloid of two or more liquids. Usually, one liquid is the 'base' and the other is broken into tiny droplets spread throughout the base liquid. Milk is an example of an emulsion, with tiny droplets of fats and oils spread throughout the base, which is water.

In some cases, when mixtures like this are left to settle, the tiny droplets float above the base liquid. (This is different from what happens in a suspension, where the solid particles tend to fall to the bottom.) A substance called an **emulsifier** can be added to these mixtures to allow the liquids to remain completely mixed.

The most common emulsions we use are mixtures of different types of oils mixed with water and an emulsifier. Examples include food and drinks, and 'emulsion' paints for walls and ceilings.

emulsion
a colloid of two or more liquids

emulsifier
a substance that enables oil and water to form an emulsion

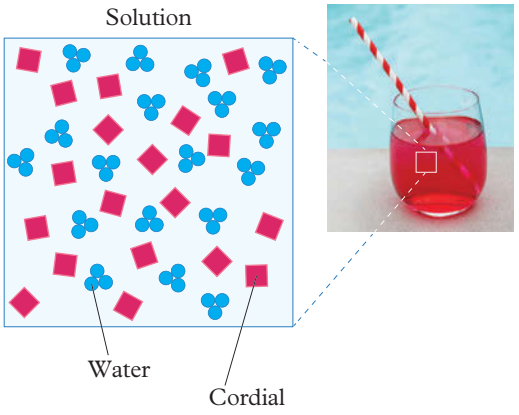


Figure 2 This glass of cordial is an example of a solution. The small cordial particles are dissolved evenly throughout the water. The swimming pool water in the background is also a solution, with chlorine and other chemicals dissolved evenly in the water.

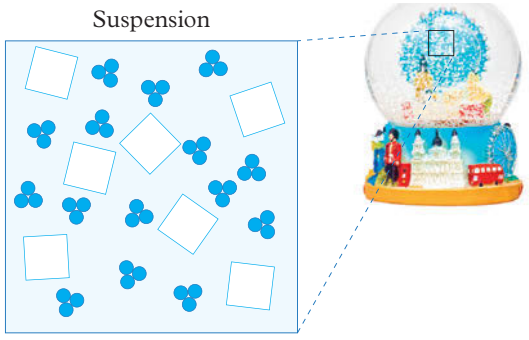


Figure 3 A snow dome can be described as a suspension, with the larger 'snow' particles being suspended in the water for a short time before they fall to the bottom of the dome to form a sediment.



Figure 4 Milk is a colloid because it contains many substances suspended in what is mainly water.

Check your learning 17.1

Recall and explain

1 **Explain** the difference between a mixture and a pure substance.

Apply and analyse

2 **Classify** the following as pure or not pure.
- **a** Cup of tea
- **b** Soft drink
- **c** Table salt
- **d** Soap
- **e** Olive oil

Apply and analyse

3 For any item in question 2 that you think is not pure, **predict** what substances you think it may contain.

4 In which mixture(s) would you find sediment?

5 What type of mixture is a muddy river? How do you know?

6 Why do some mixtures appear cloudy when light shines through them?

Skills builder: Processing and analysing information

7 Complete the following table to summarise information about mixtures found in this topic. (THINK: What information does each column need? Read the headings carefully.)

Type of mixture	Substances involved	Appearance when light shines through	Separates on standing?	Example
Suspension	Solid + liquid	Cloudy	Yes, slowly	Milo in milk
Emulsion				
Colloid				
Solution				

17.2 A solution is a solute dissolved in a solvent

*

In this topic you will learn that:

- aqueous mixtures dissolve a solute in a solvent to make a solution.

Solubility and insolubility

concentration
how much solute is dissolved in a solvent

dilute
containing a small number of particles in the volume of solution

concentrated
containing a large number of particles in the volume of solution

saturated
a solution in which no more solute can be dissolved

dissolved
when a solute forms a solution

In some places in Australia, the water from the local water supply has an unpleasant taste. Or washing with soap is difficult because the water forms a scum instead of a foamy lather. In these cases, the water contains metal salts that affect its taste and behaviour. Because they are so small, these metal salts do not fall to the bottom, or float on the top, but remain evenly spread through the liquid. The resulting mixture (a solution) is clear (transparent) – light will shine through it. We say that the metal salts have **dissolved** in the water.

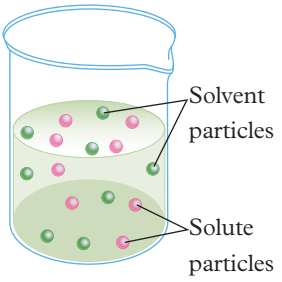


Figure 1 A solute dissolves in a solvent to create a solution.

Working with solutions

You have seen that a solution is a solute dissolved in a solvent. Solutions can be compared in terms of their **concentration**: how much solute is in the solvent. If just a little solute is dissolved, the solution is described as **dilute** (low concentration). If a lot of a solute is dissolved, the solution is described as **concentrated** (high concentration).

It is only possible to dissolve a certain amount of a particular solute in a solvent. If no more solute can dissolve into a solution, the solution is described as **saturated**.

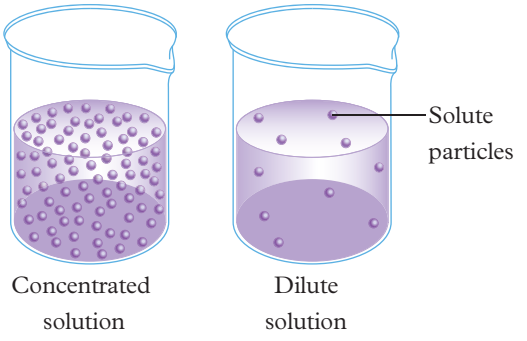


Figure 2 A concentrated solution contains more solute particles in a given volume than a dilute solution.

soluble
can be dissolved in a liquid

insoluble
does not dissolve

solute
a substance that dissolves in a liquid (solvent)

solvent
any liquid that dissolves other substances

aqueous solution
a solution where the solvent is water

A substance that is able to dissolve in a liquid is considered to be **soluble**, whereas one that cannot is **insoluble**. The substance dissolving is called the **solute**, and the liquid into which it dissolves is called the **solvent**. Sometimes it is necessary to help a solute dissolve. Heating the solvent is the most common way of making a solute dissolve faster. The resulting mixture is called a solution. If the solvent being used is water, we call this an aqueous mixture or **aqueous solution**.



Figure 3 The concentration of salt in the Dead Sea in Israel is so high that when people try to swim in it, they float instead.

INVESTIGATION
17.2: What if salt was dissolved in water?
Go to page **403**.

We often work with solutions in our everyday lives. By adding solutes to pure liquids, the properties of the pure liquids may change. An example is adding bath crystals to a bath to give a pleasant smell.

Water as a solvent for life

Water is a good solvent. This is one of its most important properties. Water is especially important for living organisms – humans, plants and animals alike. This is because water dissolves many important nutrients and minerals required for plants and animals to function. Did you know that humans can survive longer if they had only water and no food and not the other way around? Our bodies are more than 70% water. Our blood, which is mainly water, transports oxygen to every cell and carries away dissolved carbon dioxide gas (a waste product).



Figure 4 Oxygen dissolved in water is essential for the survival of aquatic organisms.

Humans are not the only living things that depend on water as a solvent. Did you know that oxygen from the atmosphere is dissolved in our oceans and lakes to be used by marine life? The amount of dissolved oxygen in our waterways is an important indicator of how healthy the water is for sustaining life. Without water's ability to dissolve gases, there would be no underwater life in our oceans and no fish in the rivers. These creatures all live by extracting dissolved oxygen gas from the water.



Figure 5 Wood fibres are added to water to make wood pulp. The water brings the fibres together, which can then be moulded into paper sheets. The water is then squeezed out.

Water as a solvent for industry

Another important use for water is in industry. Many different types of chemicals dissolve in water. This means that important chemical reactions can take place that wouldn't ordinarily occur if the substances being reacted were in their solid state. Water is an important part of making paper too. It is used in nearly every part of the process (see Figure 5).

Check your learning 17.2

Recall and explain

1 **Describe** an aqueous solution.
2 **Explain** how you could increase the amount of a solute that will dissolve in a solvent.
3 **Explain** why a solution will not allow any more solute to dissolve.
4 True or false: You can see the particles of a solute in a solution.

Apply and analyse

5 If someone asked for a dilute glass of cordial, would you add a lot of cordial or only a little?
6 Do all solutes dissolve in water? **Explain** your answer.
7 An example of an aqueous solution is detergent. **Identify** the solute.

Evaluate and create

8 Are the particles in a suspension, colloid or emulsion soluble? **Explain**.

Skills builder: Questioning and predicting

9 **Predict** what would happen to a teaspoon of sugar particles when the particles dissolve in a cup of water. (THINK: What do you know about solutions, solutes and solvents?)

17.3 Mixtures can be separated according to their properties

In this topic you will learn that:

- a mixture contains components that can be separated because of their different properties
- separation techniques are important for our environment.

Video
Separation technique: magnetic

A mixture contains components that can be separated because of their different properties. Properties are how a substance looks (size, mass, texture, shape, volume) and how it behaves around other substances (magnetic, soluble). Before you can separate a mixture, you need to find out what properties its components have that are different. For example, one substance may be soluble in water, whereas another may not. One substance may be magnetic and another not magnetic.

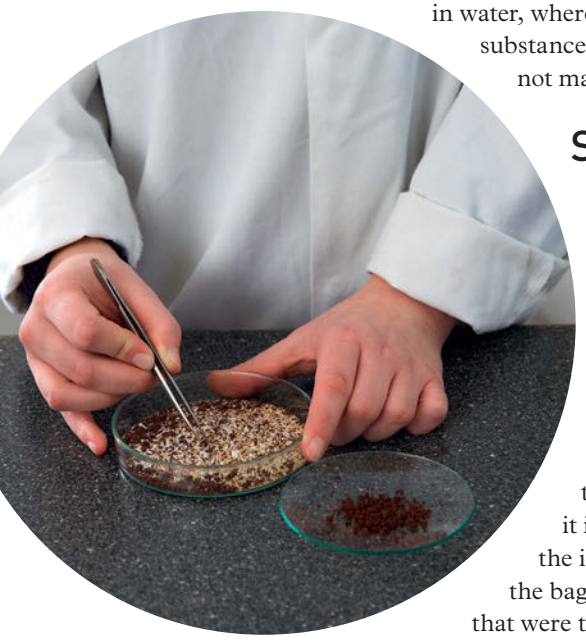


Figure 1 Different separations need different techniques.

Simple separation

Some mixtures are quite simple to separate. Sometimes we can simply pick out the bits we need to separate. A bag of mixed lollies may contain a few of your favourites. You could easily use your fingers to pick these lollies out so that you could eat them first. This works well if it is a small bag and you can see the individual lollies. But what if the bag contained hundreds of lollies that were too small to see? You may need another way of separating out your favourites.

Magnetic separation

Do you separate recyclables from your rubbish? Have you ever wondered how the different recyclable materials are separated once they're out of your house?

Magnetic separation uses magnets to attract and separate particular metals. Some objects are magnetic. Magnetic substances are attracted to a magnet. They are made of iron, or a mixture containing iron.

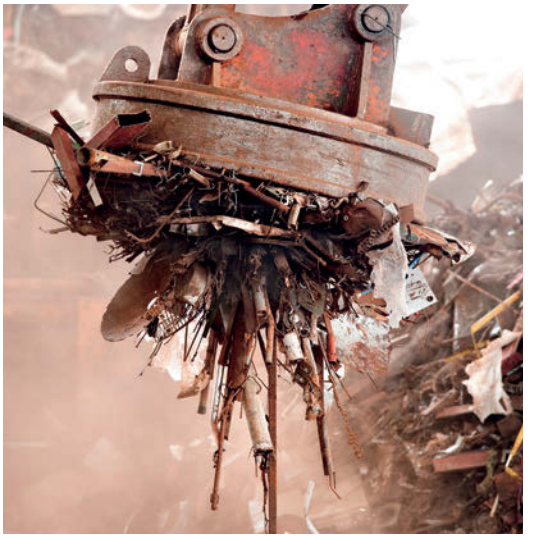


Figure 2 Magnets are used to separate metals in recycling plants.

Because magnetism will only separate substances containing iron, magnetic materials, such as iron nails, can be separated from other non-magnetic materials, such as glass, aluminium and paper.

Tin cans are magnetic, whereas aluminium cans are not. Sometimes large magnets are used to separate aluminium cans in the rubbish from tin cans. This means both types of cans can be recycled in different ways.

Decanting, sedimentation and flotation

Have you ever had a piece of food in the bottom of your drink? Did you use a spoon to remove it? Or maybe you carefully poured your drink into another glass, leaving the food behind? The careful pouring of liquid, or **decanting**, is often done to remove sediment from wine.

magnetic
able to be magnetised or attracted by a magnet

decanting
a separation technique used to separate a sediment from the liquid it is in by carefully pouring the liquid away

SKILLS LAB **17.3A:** Separating mixtures using sedimentation and flotation
Go to page **403**.

SKILLS LAB **17.3B:** Separating using magnetic properties
Go to page **404**.

INVESTIGATION **17.3:** What if a flocculent was added to muddy water?
Go to page **404**.



Figure 3 Sewage treatment involves sedimentation and flotation.



Figure 4 Oil floats on the surface of water.

The objects or liquids that sink are denser than the liquid on the top. The particles in dense objects are packed together more tightly than in less dense objects. Oil floats on top of water because the particles in the oil are packed very loosely. The water particles pack together more tightly, so they sink to the bottom, below the oil.

The particles in a grain of sand are packed together very tightly. The sand is more dense than water. Therefore, the sand settles to the bottom of a glass of water. The sand forms a sediment in the glass.

Sedimentation and flotation are used in sewage treatment to separate the mixture of substances. Sewage is left in settling ponds to allow the sediment to settle to the bottom. Fats and oils that float to the top of the ponds can be scooped off for digestion by bacteria.

Oil spills can be cleaned up using the fact that oil floats on the surface of water. Cork and other substances can be sprinkled on top of the oil to soak it up, and these substances are then scooped off and squeezed out.

In certain situations, sedimentation is more difficult. Chemicals called **flocculants** can be added to a mixture to make suspended particles clump together. This makes them heavy enough to settle to the bottom. Flocculation is regularly used to separate substances from water.

flocculant
a chemical added to a mixture to make suspended particles clump together

sedimentation
a process that uses gravity to remove suspended solids from a solution

Check your learning 17.3

Recall and explain

1 **Recall** what the following words mean.
- **a** Sediment
- **b** Flocculation
- **c** Decant
- **d** Density

Apply and analyse

2 **Explain** why flotation allows oil spills to be cleaned up more easily.

3 If a suspension doesn't separate, **propose** a method to cause sedimentation.

4 In what situation might you rely on people to separate a mixture by hand?

Evaluate and create

5 **Discuss** the limitations for using magnetism to separate a mixture.

Skills builder: Planning investigations

6 You've been asked to separate a mixture of sand, iron filings and chocolate chips. **Identify** a list of equipment you will need to perform this task. (THINK: What separation processes will you need to perform? What equipment do each of these processes need? What about safety equipment?)

17.4 Mixtures can be separated using their size and mass



Figure 1 Tea bags are a common household filter.

In this topic you will learn that:

- large particles can be separated from smaller particles by filtering
- heavy particles can be separated from light particles by using a centrifuge.

Video
Separation technique: filter paper

Filtering and sieving

Anyone who has cooked pasta will probably have used a colander or sieve to separate the boiling water from the cooked pasta. The holes in the colander or sieve are designed to let the water through, but not the pasta.

A filter has a series of holes in it that lets through small things but traps the larger particles. A grate on a storm water drain is an example of a filter. The grate lets the water through while filtering out the leaf matter and rubbish. Fly screens on windows and doors filter bugs and some dust from the air, and tea bags filter the leaves from the liquid.

Sieving separates substances according to the size of their particles. When you use a sieve, anything that is smaller than the hole can pass through, which can be a solid or liquid; the larger solids are left behind in the sieve.

Sieves can separate solids of different sizes. **Filtering**, on the other hand, separates solids from liquids (or solutions) as the particles of the solution or liquid are smaller than the size of the holes in the **filter paper**. The **filtrate** passes through the filter and the **residue** is left behind in the filter.

Filter paper is like a paper sieve with holes that are too small to see. Solutions can flow through the filter paper because the particles in the solution are small enough to fit through the holes; however, most solid particles in suspensions are not. Different filter papers come with different-sized holes. Coffee filters and the filters found in vacuum cleaner bags are both made of paper filters. HEPA (high-efficiency particulate air) filters are used in vacuum cleaners, air conditioners and face masks to remove even tiny dust particles.

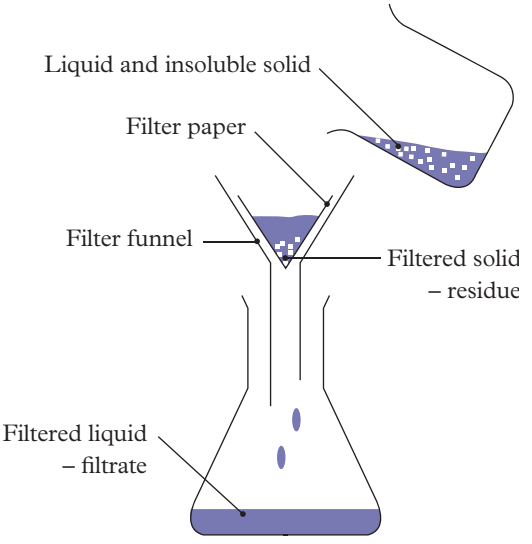


Figure 3 Filters are used in science to separate substances. Particles that pass through the filter are called the filtrate. The filter paper traps the residue.

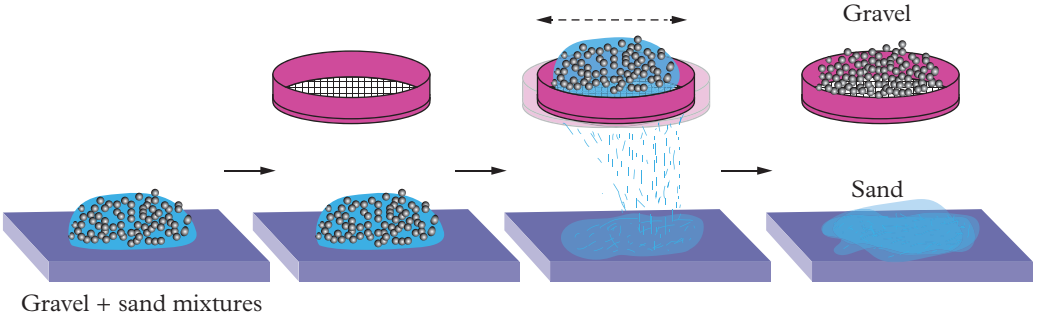


Figure 2 Sieves can be used to separate solids of different sizes, such as gravel and sand.

sieving
a separation technique used to separate different-sized particles depending on the holes in the sieve used

filtering
a separation technique used to separate solids from liquids or solutions, depending on the size of the holes in the filter paper

filter paper
a paper sieve with tiny holes that are too small to see; solutions can flow through but most solid particles cannot

filtrate
the substance that passes through a filter

residue
the substance left behind in a sieve or filter

SKILLS LAB **17.4:** Filtering a mixture of sand and water
Go to page **405**.

INVESTIGATION **17.4:** What if you centrifuge milk?
Go to your obook.

Sometimes filters remove substances using chemicals rather than by physically stopping them. Gas masks often contain a special type of charcoal that attracts and holds onto some poisonous gases.



Figure 4 A gas mask uses activated charcoal to filter poisonous gases.

Centrifuging

Sometimes mixtures do not separate well using sedimentation because the particles are not dense enough. Sometimes things need to be separated using their weight.

Some playgrounds have equipment that spins around very fast. When you spin very fast on this equipment, you can feel a force pulling you towards the outside of the spin. Heavy objects feel the pull more than light objects.

Centrifuging separates light and heavy particles by spinning a mixture. A centrifuge is a machine that spins very quickly. In a laboratory, small test tubes of mixtures are fixed to the inside of the bowl of the centrifuge. The spinning motion causes the heavier particles to move to the bottom of the tubes.

Centrifuges are used in medical research and at blood banks. When blood is spun in a centrifuge, the red blood cells, which are heavier, sink to the bottom of the test tube, leaving the yellowish liquid part of blood (plasma and platelets) at the top. Medical professionals use different parts of blood depending on the particular medical need.

Centrifuges are used in dairy processing factories to separate cream from milk. Salad spinners and washing machines also use this principle.

centrifuging
a separation technique used to separate light particles from heavy particles by rapidly spinning the mixture in a container (called a centrifuge)

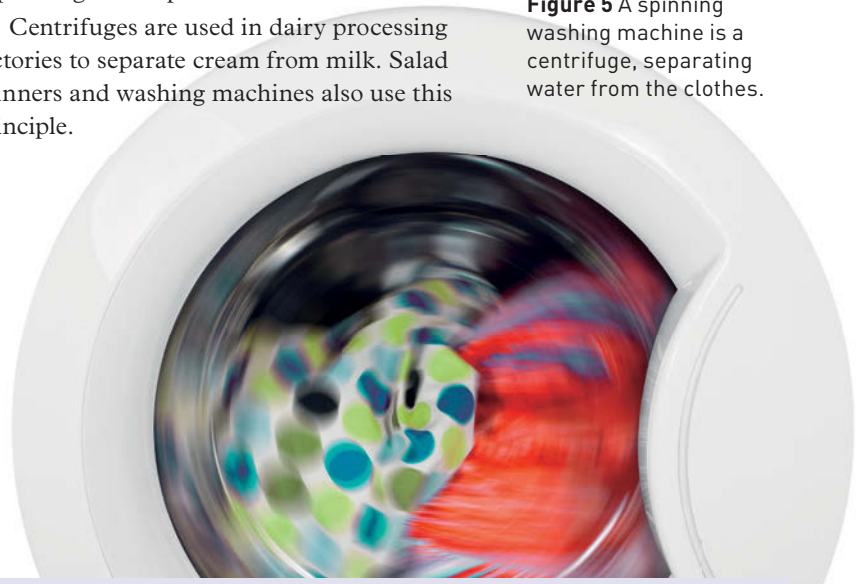


Figure 5 A spinning washing machine is a centrifuge, separating water from the clothes.

Check your learning 17.4

Recall and explain

1 **Identify** some of the filters that are used around your home and school. What substances do these filters allow to pass through them, and what substances do they collect?

2 For each of the following pairs, write a sentence **explaining** the difference between them.
- **a** Mixture – pure substance
- **b** Sedimentation – flotation
- **c** Residue – filtrate

3 Complete the sentences below by filling in the missing words.
Filtering is like using a _____. The _____ lumps are caught in the sieve, and the _____ goes through the _____ paper. The substance caught in the _____ paper is called the _____. The substance that passes through is called the _____.

Apply and analyse

4 Why would a forensic scientist who was investigating a crime want to compare a mixture of different types of sand found in a suspect's car with a similar mixture found at the crime scene?

5 Is a butterfly net an example of a filter? **Explain**.

Skills builder: Problem solving

6 A doctor needs to extract plasma and platelets from a patient's blood. She is given two options to perform this task: a centrifuge and a filter.
- **a** **Identify** which of these separation techniques the doctor should use. (THINK: What is the best way to separate two liquids that have different densities?)
- **b** **Justify** your choice. (THINK: Why did you choose this option? Why not the other?)

17.5 The boiling points of liquids can be used to separate mixtures

In this topic you will learn that:

- the various substances in a mixture can have different boiling points, so they become a gas at different temperatures
- crystallisation and evaporation use different boiling points to separate mixtures.

Video
Separation technique: Distillation

Video
Separation technique: Evaporation

Filtering, sedimentation, flotation, centrifuging and magnetic separation are useful for some types of separation. But what do you do when they don't work?

Evaporation and crystallisation

When water in a saucepan is heated, it will quickly start to boil. This means the liquid **evaporates**: it becomes a gas. Every substance evaporates at a different temperature. Table 1 shows the **boiling points** of some common liquids.

evaporate
to change in state from liquid to gas; also a separation technique used to separate dissolved solids from water

boiling point
the temperature at which a liquid boils and turns to a gas

Table 1 Boiling points of common liquids

Liquid	Boiling point (°C)
Water	100
Alcohol	78
Petrol	95
Olive oil	300
Tar	300
Turpentine	160

The different boiling points of liquids can be used to separate them in a mixture. A mixture of water and turpentine can be easily separated because the water will evaporate first. This means the water will become a gas (steam) and move away from the turpentine. Eventually only turpentine will be left behind.

Evaporation can also be used to separate the parts of a solution. Salt evaporates at 1414°C. When a mixture of salt and water is heated, the water evaporates first, leaving behind the salt crystals. This process of evaporating the solvent (the water) and leaving behind the solute (salt) is called **crystallisation**.

crystallisation
a separation technique used in conjunction with evaporation to remove a dissolved solid from a liquid; after the liquid has been evaporated the solid remains, often in the form of small crystals



Figure 1 Water will evaporate when it reaches boiling point.



Figure 2 Water will evaporate from a mixture of salt and water, leaving behind salt crystals.

INVESTIGATION
17.5: Crystallisation of salt water
Go to page **406**.

CHALLENGE
17.5: Designing a way to purify water from sea water
Go to page **406**.

Distillation

What if we want to keep the substance that has the lowest boiling point? Collecting drinkable water from sea water is difficult if all the water evaporates into the air. **Distillation** is a way of collecting the gas that evaporates from a mixture and cooling it down so that it becomes a liquid again (see Figure 3). This cooling of a gas into a liquid is called **condensation**.

The crude oil that is removed from the earth is a mixture of different liquids that all have different boiling points. When the crude oil is heated, petrol is one of the first to evaporate. The petrol gas rises up the column until it cools and condenses. The liquid petrol is then collected on one of the trays in the column. The oil used in heating has a higher boiling point. It evaporates more slowly and condenses more quickly. It is collected on a tray lower in the column.



Figure 4 Crude oil can be separated into different fuels because each boils at a different temperature.

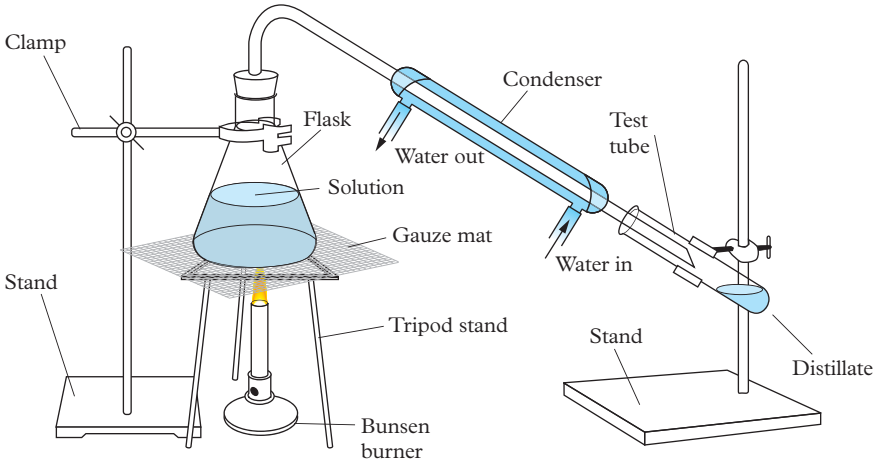


Figure 3 Equipment set-up for distillation

distillation
a separation technique that uses evaporation and condensation to separate a solid contaminant and the solvent in which it has dissolved (e.g. to get pure water from salt water)

condensation
the change of state from a gas to a liquid; occurs when a gas cools down

Check your learning 17.5

Recall and explain

1 **Explain** the difference between evaporation and crystallisation.

Apply and analyse

2 **Identify** an example of a mixture you would separate using evaporation and crystallisation. **Explain** why distillation would not be appropriate.

3 **Identify** the separation technique being conducted in Figure 5.



Figure 5 Separation experiment

Skills builder: Conducting investigations

4 Draw and label the equipment set-up that could be used to produce pure water from sea water by distillation. (THINK: What equipment do you need for distillation and how could it be assembled?)

17.6 Solubility can be used to separate a mixture

In this topic you will learn that:

- some substances are able to dissolve more easily than others
- chromatography can be used to separate mixtures of substances that have different solubilities.

solubility
how easily a substance dissolves in a solvent

chromatography
a separation technique used to separate substances according to differing adsorption to a surface (e.g. coloured dyes that make up pen ink)

Solubility

Solubility describes how easily a substance dissolves in a solvent. Some dyes have a higher solubility than others. This can be used to separate them from each other. Many dyes are small particles that are suspended in a solvent. They are usually made from plants or minerals. Around 2000 BCE, the ancient Egyptians and Chinese both made a mixture of soot and vegetable gum that could be used for writing. The ancient Chinese also made red ink from mercury sulfate and black ink from iron sulfur by mixing it with sumac tree sap. Today, many of the inks in textas are made of a mixture of these dyes. We can separate these dye mixtures because the dyes have different solubilities.

Chromatography

Paper chromatography is a common way to separate a mixture. **Chromatography** works when the end of the absorbent paper is dipped in water, allowing the water to slowly move up the paper. As the water moves past the dye mixture, the most soluble dye dissolves and starts to move with the water. The other dyes in the mixture take longer to dissolve. Eventually, the next dye forms a solution and starts moving towards the top of the paper. Finally, the paper has a series of smudged dyes running up to the top. The coloured dye that is the most soluble is at the top, whereas the dye that is least soluble is at the bottom.



Figure 1 Chromatography is used to separate samples, such as inks and dyes.

CHALLENGE
17.6A: Who wrote the nasty note?
Go to page **407**.

CHALLENGE
17.6B: Separation challenge
Go to page **408**.



Figure 2 Performing gas chromatography

More complex and sensitive chromatography instruments are used to separate mixtures such as drinks and polluted air. Science laboratories often contain instruments that can be used to detect even 1 gram of a substance present in thousands of litres of solution. Scientists use chromatography to find out what substances are in a mixture. Different substances will move through at different times. The height of each peak tells the scientist how much of a particular substance there is.

One of the uses of chromatography today is to identify athletes who use banned substances when they compete by testing their urine. A chromatography machine separates all the substances in the urine, including any illegal drugs that leave the body in this way.

Airport security also tests for illegal drugs in this way. A piece of chromatography paper is wiped over a person or their bag and then inserted into a machine. A gas is pushed through the paper. If the drug is soluble in the gas, it will dissolve and be detected by the sensors. An alarm sounds and the security guard will take the person for questioning.



Figure 3 Airport security uses chromatography to test for illegal drugs.

Check your learning 17.6

Describe and explain

1 **Explain** how chromatography can separate inks and dyes.
2 **Identify** when you might use chromatography to separate substances.
3 **Recall** the solvent used in chromatography when testing for drugs at airports.
4 What does 'solubility' mean?

Evaluate and create

5 **Investigate** an occupation that would use chromatography. Write a short profile that communicates why someone would use chromatography to do that job.

Skills builder: Planning investigations

6 Using scientific language, write a logical procedure for separating the ink in textas (or felt-tip pens) using paper chromatography.

(THINK: What order do you need to perform each step? Use the information to recall how chromatography works.)
Remember that when you write a method, you should start each step with a verb and use the third person – avoid 'I', 'we' and 'you'.

17.7 Wastewater is a mixture that can be separated

In this topic you will learn that:

- physical separation techniques can be used to treat wastewater.

Washing the dishes or using the bathroom produces wastewater that contains a mixture of vegetable matter, paper, cloth and plastics. This cannot be released directly into the waterways without harming the environment. Scientists use their knowledge of separating mixtures to make the water safe to use.



Figure 1 A water treatment plant

Many unusual things have been found at water treatment plants, including BMX bikes, toys, false teeth and even money. One of the biggest problems currently is the small stickers found on fruit. If eaten accidentally, the small plastic stickers pass through the digestive system and end up at the water treatment plants.

Primary treatment

Initially, the wastewater is filtered to remove any large products. This includes cotton buds, rags and the stickers found on fruit. Aluminium sulfate is added to the wastewater to encourage any suspended particles still remaining to coagulate or clump together. This process is called flocculation (see Figure 2).

The small clumps are then left to sit in sediment ponds. This allows the clumps to form a sediment on the bottom of the pond. This sediment is called sludge and can be removed and disinfected. Many industries use the sludge as fertiliser or to manufacture biofuels.

Secondary treatment

The remaining wastewater often contains levels of nutrients, such as nitrogen and phosphorus, that would be harmful to rivers or the ocean.



Figure 2 Flocculation results in the clumping together of suspended particles in wastewater.



Figure 3 An algal bloom

When these nutrients enter waterways in large amounts, algae feed off them and grow into large blooms (Figure 3). The large numbers of algae use all the oxygen and nutrients in the water, leaving other aquatic life to starve. Secondary waste treatment pumps the wastewater through a series of tanks where bacteria remove the excess nutrients from the water.

Tertiary treatment

Sometimes the water will be treated at a tertiary treatment plant. Once again the water is filtered to remove any particles that may be left in the water. Chlorine can be added (just like a swimming pool) to kill any bacteria that may still be in the water.



Figure 4 Chlorine and wastewater tanks in a tertiary water treatment plant

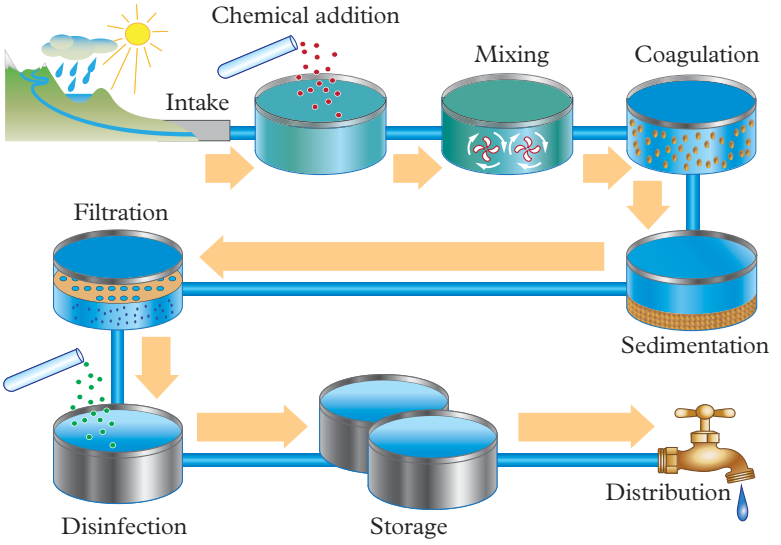


Figure 5 Summary of the water treatment process

Check your learning 17.7

Recall and explain

1 **Describe** what types of objects might be removed during the primary treatment of wastewater.

2 **Outline** how an algal bloom can damage a river.

3 **Identify** the purpose of the tertiary treatment of wastewater.

Apply and analyse

4 Water use is often an indication of the amount of wastewater produced per person every year. **Interpret** the graph of annual water consumption per person shown in Figure 6.

- a **Identify** which city uses the highest amount of water per person each year.
- b **Identify** which city uses the lowest amount of water per person each year.
- c **Interpret** how much water the average person uses in Canberra.
- d **Deduce** why a person living in Brisbane uses more water than a person living in Sydney.

5 **Identify** which steps are a physical separation process in the water treatment process in Figure 5. **Justify** your response.



Figure 6 Annual water consumption per person

Evaluate and create

6 Draw a cartoon that shows one stage of the treatment process. Join your cartoon with those from others in your class who drew the other two stages, so that combined you show all levels of the water treatment process.

Skills builder: Communication

7 Consider the information you extracted from the graph in question 4. Write a paragraph using scientific language that explains how water is used across Australia each year. (THINK: What are the key points to highlight? Write this information objectively – using facts, no opinions, and writing in the third person.)

17.8 Materials recovery facilities separate mixtures

In this topic, you will learn that:

- a materials recovery facility uses the mass, colour and magnetic properties of items to separate them so that they can be recycled.

Household recyclables

Have you ever wondered what happens to the rubbish in the recycling bins collected by your local council? Most households put their paper, cardboard, glass bottles, cans and recyclable plastics into a separate rubbish bin. These items are collected by a different truck from the general rubbish trucks. Instead of going to landfill, the trucks take the recyclable rubbish to a materials recovery facility. As the name suggests, this facility separates the mixture of rubbish before sending it off to be recycled.



Figure 1 A materials recovery facility

The materials recovery facility

At the materials recovery facility, the truck unloads the recycled rubbish onto a conveyer belt. The conveyer belt carries the rubbish into the facility before allowing the rubbish to drop onto a slight incline belt. Paper, cardboard and other light rubbish stay on the incline belt, and are carried up and along to where they are sorted by hand. People separate the paper from the plastic bags, placing each into their special bins for recycling.

Heavier objects, such as larger plastic containers, aluminium and tin cans, fall backwards off the incline conveyer belt onto another moving belt. This conveyer belt uses a large magnet to separate the steel and tin cans into a large bin. Aluminium cans are not attracted to the magnet and remain mixed with the larger glass and plastic containers.

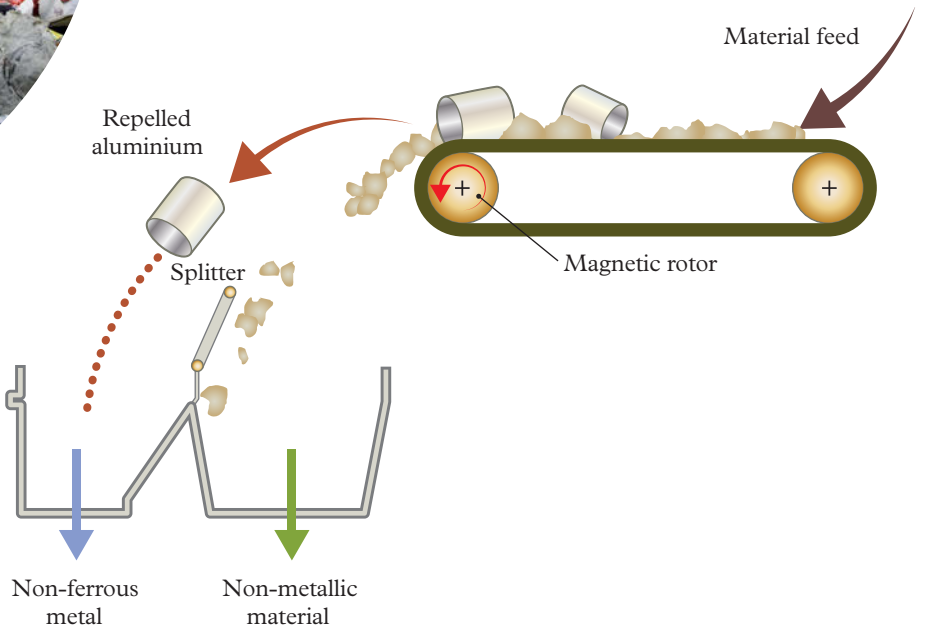


Figure 2 How an eddy current separator works

The aluminium cans, glass and plastics are exposed to a special eddy current separator (see Figure 2). This separator pushes the aluminium cans away so that the cans fall further than the glass and plastic bottles.

The conveyer belt carries the remaining glass and plastic bottles forwards over a pit. The heavier glass containers fall faster and are collected in a bin. The lighter plastic containers are caught by the last conveyer belt and are separated on the basis of colour. A light scans each plastic container for the type of plastic. Each type of recycled plastic is a different colour. Each colour plastic receives a different blast of air that projects it into the correct bin.

Why recycle?

Recycled glass is crushed into a 'cullet' and heated to 1500°C until it is liquid/molten. The molten glass is then poured into a mould to form new bottles. The energy saved from recycling one glass bottle will run a 100 watt light globe for four hours. Aluminium cans are recycled in a similar manner. Each aluminium can that is recycled will create enough electricity to run a television for three hours. Recycling 1 tonne of paper and cardboard will save 13 trees.

Check your learning 17.8

Describe and describe

1 **Identify** what property allows the separation of:
   - **a** different types of plastics
   - **b** glass and plastic
   - **c** aluminium cans from glass and plastic
   - **d** steel and tin cans from the recycling rubbish
   - **e** paper and cardboard from the recycling rubbish.

2 What is molten glass?

3 **Explain** why people need to separate paper from plastic bags when recycling.

4 **Identify** the types of recyclable materials that are collected in your area. Where is your nearest recycling facility?

Apply and analyse

5 Split into five groups. Each group should work together to **describe** what is happening at one of the stages labelled in Figure 3.

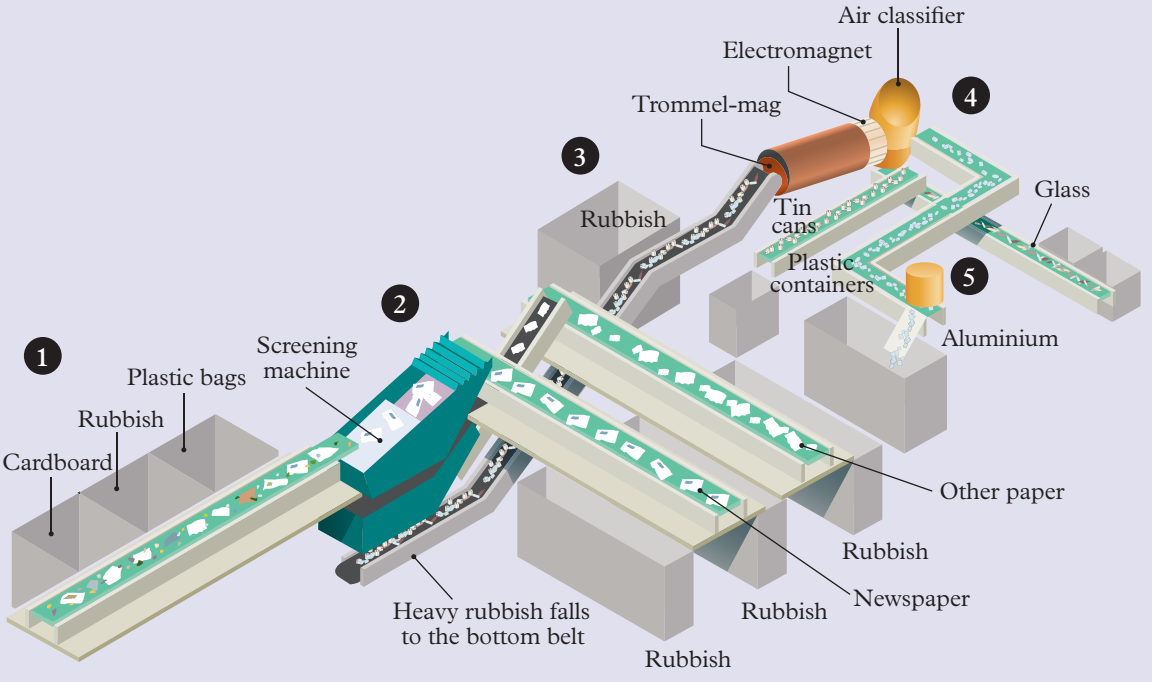


Figure 3 An illustration of a materials recovery facility

Skills builder: Questioning and predicting

6 **Predict** what would happen to an eddy separator (see Figure 2) if the magnetic rotator was not working. (THINK: What role does the magnet play in the separation process? What would happen to the production line without it?)

REVIEW

Multiple choice

1 A tablet is dissolved in a glass of water. **Identify** the solvent in the scenario.

A The tablet
B The water
C The glass
D The tablet and water combined



Figure 1 A tablet in water

2 What physical property allows mixtures to be separated by decanting or sedimentation?

A Boiling point
B Magnetism
C Density
D Compressibility

3 **Identify** which separation technique can be used to separate liquids with different solubilities.

A Evaporation
B Distillation
C Magnetic separation
D Chromatography

Recall and explain

4 **Describe** the importance of water as a solvent in daily life.

5 **Recall** what an aqueous mixture is. Give an example.

6 **Define** the term 'solution'.

7 **Identify** an example of a mixture that could be separated into its parts by filtration.

8 What safety recommendations would you give to someone using evaporation and crystallisation?

9 Nail polish remover and paint stripper are both useful solvents.

a What is a solvent?
b **Identify** the solute for each solvent.

10 Complete Table 1, adding in additional lines, to include all of the different techniques described throughout this chapter. **Identify** the property that the technique exploits, a description of the technique and an example. The first one is done for you as an example.

Table 1 Separation techniques

Separation technique	Property	Description	Example
Centrifuge	Mass of particle (heaviest particles move to the bottom and the lighter particles move to the top)	A centrifuge is a machine that spins very quickly. Small test tubes of mixtures are fixed to the inside of the bowl of the centrifuge. The spinning motion causes the heavier particles to move to the bottom of the tubes.	Separation of blood into plasma and platelets (top of the test tube) and red blood cells (bottom of the test tube)

Apply and analyse

11 **Examine** Figure 2 to **identify** the suspension, solution and colloid.



Figure 2 Separation experiment

12 **a** **Identify** which separation technique is used to separate the parts of blood?
b **Identify** which physical property is being used to separate this mixture?

13 A criminal buries an aluminium drink can containing DNA evidence in the sand. Could the aluminium can be separated from the sand using a magnet? **Explain** your answer.

14 Imagine dropping salt in sawdust. **Outline** how you would separate the parts of this mixture.

15 **Contrast** the processes of filtering and sieving. Give an example of when you would use each to separate a mixture.

16 Blood is a mixture of red blood cells, white blood cells and plasma. The device in Figure 3 can be used to separate the different components of blood. A test tube filled with blood is placed into the device which spins quickly, separating the blood cells based on their size.



Figure 3 Centrifuge

a **Identify** the type of separation taking place.

b **Identify** another example of this kind of separation.

17 Daniel was measuring the solubility of two chemicals (A and B) in water. He placed a spatula full of each substance in a separate test tube of water. Figure 4 shows what he saw.

Use the words 'dissolve', 'solvent', 'solute' and 'suspension' to **explain** what has happened in each test tube.



Figure 4 Test tube A (left) and test tube B (right)

18 Imagine that you have just bought a large factory. Due to flood damage, it is filled with tonnes of matchsticks mixed with tonnes of iron scraps.

a **Propose** a method to separate this mixture.

b **Identify** what equipment you would need to make this happen on such a large scale.

Evaluate and create

19 **Justify** whether the following substances are an element, a mixture or a compound: sea water, air, carbon dioxide, pure water, oxygen, diamond, cement, iron filings, table salt (NaCl).

20 Look at the chromatograms in Figure 3, taken from blue pens belonging to suspects (A–D). **Compare** these with the one taken from the original forged cheque (X). **Deduce** whether any of the suspects are likely to be the culprit.

21 A particular coloured dye is being created for Fashion Week.

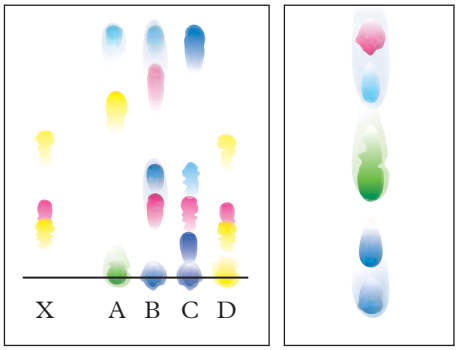


Figure 5 Chromatograms

a **Examine** the chromatogram of the dye mixture in Figure 5. **Identify** how many pure dyes were mixed to create the colour.

b **Discuss** how chromatography could help create an exact copy of the dye for a rival manufacturer.

22 People sometimes need to enter environments containing poisonous gases. In these situations, they will wear a gas mask. **Investigate** how gas masks interact with poisonous gases, and how they change the air before it is inhaled by the person wearing the mask.

Critical thinking

23 Do you think that performance-enhancing drugs are spoiling the image of sports? **Discuss** with a partner and make a list of all the implications of athletes using these drugs to compete.

24 Which techniques, and in what order, would you use to separate a mixture of iron filings, sand, marbles and salt? Present your answer as a flow chart and **justify** your order. Why is the order so important?

Going further

25 Carbon, nitrogen and oxygen flow through our environment in cycles. Research and draw a flow chart showing how oxygen moves between its elemental form and as a compound with carbon.

26 Carbon exists as either graphite, diamond or amorphous carbon. Known as 'allotropes' of carbon, research and **explain** how each of these different allotropes are made and how their properties and structure change.

27 In construction an alloy, steel, is used for beams and building frames. What are alloys? **Investigate** what steel is made from and what its properties are. Identify three other common alloys and the metals they are made from.

Research

28 Choose one of the following topics on which to conduct further research. Present your findings in a format that best fits the information you have found and understandings you have formed.

» How do we work with mixtures?

Research a separation technique that is used in a different industry or in nature. Prepare a SWOT analysis as part of your report, listing the strengths, weaknesses, opportunities and threats of the separation technique that you choose to research. You could present your report with a series of photographs of the technique.

» Filters of the sea

Certain types of whales, known as baleen whales, have a filter in their mouth made of a bone-like substance called baleen. Research what these plates do and what they filter. In addition, **investigate** how whales are different from other filter-feeders, such as barnacles, sponges and flamingos.



Figure 6 A baleen whale

» Distillation for survival

Imagine that you were hiking in central Australia, became separated from your group and then ran out of drinking water. Research some techniques of distilling water from gum leaves. As part of your report, you may like to demonstrate one technique to the class.

» Human filtration

The human body needs to control what goes into it and what comes out. In particular, the filtering system of the kidneys prevents us from being poisoned by our own wastes, and tiny hairs in our noses filter dust and germs as we breathe. Find out more about these human filtration systems and see if you can identify others.

» Self-cleaning suburbs

As our population grows, new suburbs are being built on the outskirts of cities. In some of these new suburbs, several features have been included to keep the water and air clean. Find out about strategies that are used to purify water and the air in housing estates.

Reflection

Now that you've completed this chapter, reflect on your ability to do the following:

	I can do this.	I can't do this yet.	
Describe the importance of water as a solvent in daily life, industries and the environment.	☐	☐	Go to page 306–307.
Describe aqueous mixtures in terms of solute, solvent and solution.	☐	☐	Go to page 5.
Relate a range of techniques used to separate the components of some common mixtures to the physical principles involved in each process, including filtration, decantation, evaporation, crystallisation, chromatography and distillation.	☐	☐	Go to page 308–315.
Investigate the application of a physical separation technique used in everyday situations or industrial processes, e.g. water filtering, sorting waste materials, extracting pigments or oils from plants, separating blood products or cleaning up oil spills.	☐	☐	Go to page 316–319.
Research how people in different occupations use understanding and skills from across the disciplines of Science in carrying out separation techniques.	☐	☐	Go to page 314–319.

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CHEMICAL CHANGE

How are new substances made?

Have you ever wondered ...

- Why can we melt and freeze water, but not bake and unbake a cake?
- Why does food sometimes change colour when you cook it?
- How are caves formed?

18

SCIENCE UNDERSTANDING

In this chapter you will learn how to:

- identify when a chemical change is taking place by observing a change in temperature, the appearance of new substances or the disappearance of an original substance
- demonstrate that a chemical change involves substances reacting to form new substances
- investigate some examples of chemical change that occur in everyday life, e.g. photosynthesis, respiration and chemical weathering
- compare physical and chemical changes in terms of the arrangement of particles and reversibility of the process
- propose reasons why society should support scientific research, e.g. in the development of new pharmaceuticals and polymers
- describe, using examples, how science knowledge can develop through collaboration and connecting ideas across the disciplines of science, e.g. making or obtaining new substances from Earth's spheres

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Check your Student obook assess for these digital resources and more:

QuizletLive
Compete in teams to test your knowledge.

Assess quiz
Before you start this chapter, assess your science skills.

Check your Teacher obook assess for these resources and more:

QuizletLive
Launch a quiz for your students on key concepts in this chapter.

18.1 Physical change is a change in shape or appearance



Figure 1 Ice melting to water is an example of a physical change.

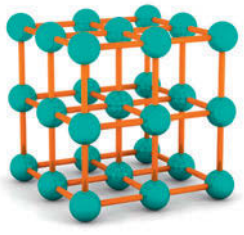


Figure 2 A lattice arrangement of particles

lattice
a three-dimensional arrangement of particles in a regular pattern

In this topic you will learn that:

- physical changes do not change the particles in a substance
- physical changes are reversible

Physical changes are reversible

One way that substances can change is through a physical change. The substance still consists of the same particles, but it looks different. Most physical changes are reversible, which means the change can be undone and the substance goes back to how it was originally. When you put water in the freezer, it turns to solid ice (Figure 1). When you take the ice out of the freezer, it changes back into water. In this way, we can deduce that a physical change has taken place because the water is still water and no new substances have been created.

For each of these substances the particle itself has not changed. The molecule of water (H_2O) that contains two hydrogen atoms and one oxygen atom is exactly the same when it is a solid, liquid or a gas. The main difference is how closely packed all the water molecules are and how much kinetic energy they have.

In ice, all the water molecules are in a regular arrangement (rows, columns and layers). A three-dimensional arrangement of particles in a regular pattern is called a **lattice**.

The water molecules in ice are constantly vibrating (Figure 2).

When heat energy is added, the water molecules vibrate faster and take up more space. However, the molecules are still held in place in the lattice by other water molecules around them. As the ice warms up, the water molecules gain more energy and vibrate faster. Eventually, they have so much energy that the water molecules break free of the others around them. The solid ice has melted to become liquid water.

Changing state

Substances can change between the three states – solid, liquid and gas (Figure 3). You are familiar with seeing water change state (when ice blocks melt), but other substances may only ever be seen in one state. Theoretically, all substances can be changed into different states if the temperature is hot (or cold) enough. Even gases, such as nitrogen, can be turned into a liquid at very low temperatures. 'Dry ice' is actually solidified carbon dioxide.

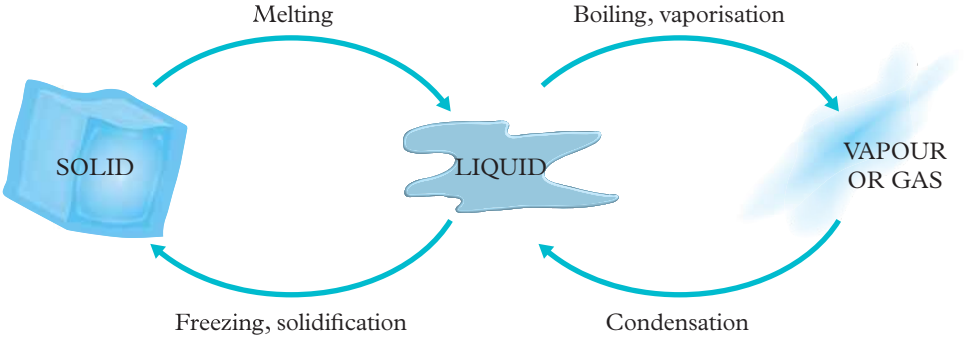


Figure 3 Changing states

CHALLENGE
18.1: Exploring physical changes
Go to page **408**.

INVESTIGATION
18.1: Melting chocolate
Go to your obook.



Figure 4 Water vapour in the air has condensed on this cold window.

Vaporisation and condensation

When a liquid evaporates to become a gas, we say it has **vaporised**. A **vapour** is the gaseous form of a substance that is normally a solid or liquid at room temperature. For example, when water is turned into a gas, it is referred to as water vapour. Vapours that are smelly are often called **fumes**. However, remember that vapours and fumes are still gases and will behave like gases.

Volatile substances such as petrol vaporise easily. Cooking oil does not vaporise if left at normal room temperatures. Cooking oil is therefore not a volatile liquid.

Boiling occurs when we heat a liquid to change it into a gas. The boiling point of pure water is 100°C. At this temperature, water changes its state to become water vapour. Water left in the open at normal room temperature will gradually evaporate. If the water is heated to its boiling point, the water will quickly gain kinetic energy and evaporate faster.

When a gas changes state to become a liquid, normally by cooling, we say it condenses (Figure 4). The most common condensation that you can observe is when water vapour in the air (or your breath) condenses on a cold surface. The kinetic energy of the water particle passes to the surface as heat energy. The water particle slows its movement and becomes liquid water.

Melting and solidification

When a solid is heated and changes state to become a liquid, we say it has **melted**. When the liquid loses heat and becomes a solid, it is called solidification. When solidification happens to water, it is also called freezing.

Sublimation

Some substances don't ever exist as liquids. They just change state from a solid to a gas or from a gas to a solid. This process is called **sublimation**. Dry ice changes directly from a solid into a gas (Figure 5). It is often used to produce smoke effects on stage at concerts. However, the 'smoke' you see is not carbon dioxide but clouds of water. When dry ice sublimates to form carbon dioxide gas, it cools the air quickly, causing water vapour in the air to condense and form clouds of carbon gas.

melt
to change state from a solid to a liquid

vaporise
to change state from a liquid to a gas; same as to evaporate

vapour
the gaseous form of a substance

fume
smelly vapours

volatile
when a substance evaporates to become a gas at room temperature

sublimation
the process of becoming a gas from a solid, bypassing the liquid phase

boil
to change state from a liquid to a gas



Figure 5 Dry ice does not form a liquid. Instead the particles sublimate.

Check your learning 18.1

Recall and explain

1 **Describe** what the following words mean.
   - **a** Lattice
   - **b** Sublimation
   - **c** Condense
   - **d** Volatile

Apply and analyse

2 A student claimed that the bubbles in boiling water were oxygen. Are they correct? **Explain** your answer.

Evaluate and create

3 Liquefied Petroleum Gas (LPG) is a gas that can be used for barbecues. **Investigate** what state LPG is stored as. What kind of change takes place when LPG comes out of a cylinder?

Skills builder: Communicating

4 **Construct** a visual aid to demonstrate the three major states of water and the physical changes water goes through to form ice and water vapour. (THINK: How could you represent this information visually? Would you use a flow chart, a diagram or a table?)

18.2 A chemical change produces new substances

*

In this topic you will learn that:

- chemical changes produce new substances
- a chemical change is irreversible.

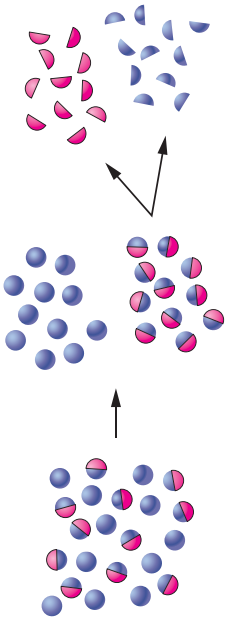


Figure 1 In a physical change, only the appearance of the substance changes because the particles have been rearranged. In a chemical change, new chemicals are made. These new chemicals are made of new particles.

When substances interact by heating, mixing or applying a force, they may change. The changes can be noticed in many ways, such as by a change in colour, the formation of bubbles, a change in temperature or the formation of solids. To understand physical and chemical changes, we can consider what happens to the particles that make up substances.



Figure 2 A gas is produced, which we either see as bubbles or fizz or smell.



Figure 3 Light or heat is absorbed or produced, which we know because the container gets cold or hot.

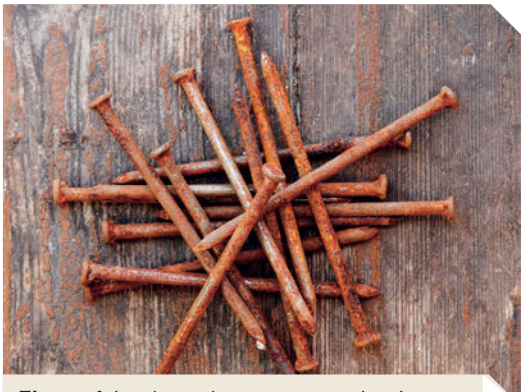


Figure 4 A colour change occurs that is non-reversible. Heating an iron nail to red hot is a physical change because the red colour will disappear as the nail cools down. However, if the iron in the nail reacts with air and becomes rusty, it is a chemical change.

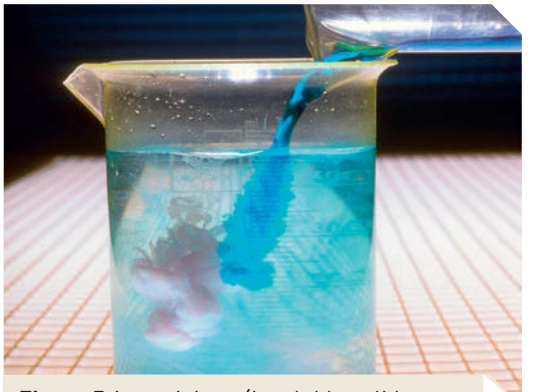


Figure 5 A precipitate (insoluble solid substance) forms that does not go away.

INVESTIGATION
18.2: Observing chemical reactions
Go to page **409**.

Chemical changes

In a chemical change, a new chemical is made. This means that the atoms have been moved around into new arrangements. In some chemical changes, atoms can be separated to make new chemicals. Sometimes atoms and molecules join together to make new chemical substances with larger molecules. New substances have new particles and new properties. Both the physical and chemical properties of the new substance (the **product**) will be different from those of the original substance (the **reactant**).

In every chemical reaction, one or more substances are changed into new, different substances with different physical and chemical properties. Chemical changes are usually not reversible – you cannot un-burn toast!

Whether a change is physical or chemical depends on the substances, the temperature and how you mix them.

Physical change or chemical change?

When solid chocolate is heated gradually, it melts and changes shape; when cooled, it goes back to the solid state. It may have a different shape, but it is still chocolate (Figure 7). In this situation, a physical change has taken place because the chocolate is still the same substance: it is still made up of the same particles.

However, if you heat chocolate at too high a temperature, it burns. When it cools, it no longer tastes of chocolate, but of burnt chocolate. This is a chemical change because a new substance is formed that is different from chocolate – you can tell by the taste and smell. This is why most chocolate recipes suggest heating chocolate over boiling water rather than over a hot plate – the chocolate does not get too hot and a chemical change does not take place.

When you bake a cake, mixing the ingredients together produces a physical change. Baking the cake involves a chemical change.

Cooking often turns food brown. This is due to the sugar in the food caramelising – turning into brown caramel. The change forms a new substance and is not reversible. It is a chemical change.



Figure 7 Heating chocolate slowly causes it to melt – a physical change. If it is heated quickly and at a higher temperature, the chocolate will burn – a chemical change.

product
substance you finish with in a chemical reaction

reactant
substance you start with in a chemical reaction

Interactive
Chemical and physical changes

Check your learning 18.2

Recall and explain

1 **Describe** 'chemical change', using an example.

2 **Identify** the following as physical or chemical changes.
- **a** Melting cooking chocolate into animal shapes
- **b** Burning magnesium ribbon to form a white ash
- **c** Boiling water and condensing the vapour
- **d** Dissolving magnesium in acid to produce hydrogen gas
- **e** Separating leaves from woodchips using a garden blower

Apply and analyse

3 When melted chocolate is put in the fridge, it cools quickly, producing small crystals that were not present before. This changes the taste of the chocolate. **Classify** this as a chemical or physical change.

4 **Explain** why baking a cake from egg, flour and butter is a chemical reaction.

5 When burning a candle, both chemical and physical changes are taking place. **Describe** the evidence of both of these processes in a candle.

6 Complete the table below, identifying whether the process is evidence of a physical or chemical change.

Process	Physical (P) or chemical (C) change
A nail rusting	
Stomach digestion	
A snowman melting	
A tree burning	
Adding Milo to cold milk	
Breaking a window	

Skills builder: Questioning and predicting

7 Anchal was asked to investigate the type of change that took place when an egg was heated in boiling water and cooled in cold water.
Write a scientific question for this investigation. (THINK: Is your question specific and can it be tested?)

18.3 Chemical reactions can break and reform new bonds

In this topic you will learn that:

- a chemical change can also be described as a chemical reaction
- in a chemical reaction, the atoms can separate from one another and bond together in new combinations to form new substances.

Chemical reactions

The substances that you start with in chemical reactions are called reactants. They react or change to produce new substances. The substances that you finish with are called products. They are produced in a chemical change. There may be more than one reactant and product for each chemical change.

Chemical equations

Scientists use a shorthand technique to describe what happens to reactants and products in chemical reactions. This is called a chemical equation. The reactants are written on the left-hand side and the products are written on the right-hand side. An arrow represents the chemical change.

Reactants → products

chemical reaction where one or more substances (reactants) are transformed into different substances (products)



Figure 1 How would a chemist use these cooking techniques?

For magnesium ribbon burning in air, the **chemical reaction** could be represented by the following chemical word equation:

Magnesium + oxygen → magnesium oxide
(in air) (white powdered form)

When sugar ($C_6H_{12}O_6$) is mixed with water (H_2O), there are two different compounds in the mixture. Because the two compounds are not chemically bonded to each other, they can be easily separated. Therefore, mixtures cannot be represented by chemical formulas.

Chemical reactions are all around us. They not only occur in factories – they also take place in our homes and our bodies. Every process in your body requires chemical changes. Cooking food changes it chemically so that it is more edible and easier to digest.

Reactions in cooking

Preparing and cooking food involve many physical and chemical changes to the food. There are other similarities between chemistry and cooking – some of the techniques, such as heating, mixing and filtering, used in cooking are similar to the tasks of a chemist.

There are many chemical reactions in the kitchen. Baked vegetables and meat turn brown as the sugars are caramelised. Usually the sugar comes from the breakdown of the starch granules into starch molecules, followed by a chemical change into a sugar. Other chemical changes involve the breakdown of proteins in meat. A few vitamins may be destroyed by some cooking methods.

Some chemical changes are caused by micro-organisms. Sour milk forms when a bacterium converts milk sugar (lactose) into an acid (lactic acid). The taste of sour milk is unpalatable and the large numbers of bacteria in the milk may make you sick. Cheese is made by fungi that consume the sugars in milk and cause the protein to thicken. Other chemicals are added to our food, including emulsifiers, flavourings, colourings, antioxidants and preservatives.

These chemicals help keep the food stable, improve its appearance and increase its shelf life.



Figure 2 Bacteria can cause chemical changes in dairy foods.

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INVESTIGATION
18.3: Comparing reactants and products
Go to page **410**.

Photosynthesis and respiration

An important process undertaken by plants is photosynthesis. This chemical reaction takes place mainly in the leaves of plants and is used to turn light energy into chemical energy.

During photosynthesis, carbon dioxide from the air reacts with the water absorbed from the soil, in the presence of sunlight, to form glucose (a sugar) and oxygen. A chemical called chlorophyll is also used in this process. The reaction can be written as a simple word equation:

$$\text{Carbon dioxide} + \text{water} \xrightarrow[\text{chlorophyll}]{\text{light energy}} \text{glucose} + \text{oxygen}$$

Cellular respiration, on the other hand, is a process that uses glucose and oxygen to produce carbon dioxide and water. During this process the plant releases energy. You learn more about these two processes in chapter 12.

Chemical weathering

Chemical weathering (which was addressed first in chapter 6) describes a process in which rocks are broken down by chemical reactions. For example, acid rain caused by gases present in the atmosphere can react with the chemical compounds found in rock such as limestone.

The Jenolan Caves in the Blue Mountains were created over millions of years ago. This was due to carbon dioxide in the atmosphere dissolving in rainwater as it fell. The rain entered the soil, collecting more dissolved carbon dioxide and making the water acidic. This acid water entered cracks in the limestone, which reacted with the calcium carbonate in the rock to form holes. Over time, these holes became larger and let in more water, eventually creating a large cave system. This is a complex chemical reaction, with several steps. However, some of the products include carbon dioxide and water.



Figure 3 During photosynthesis, a plant uses light energy to turn carbon dioxide and water into glucose and oxygen.



Figure 4 Pools of water in the Jenolan Caves continue to slowly weather the surrounding limestone.

Check your learning 18.3

Recall and explain

1 Complete the following table. In the final column, include details about the substance's properties near a flame.

Substance	Formula for substance	Colour	State at room temperature	Chemical properties
Hydrogen				
Oxygen				
Water				

2 **Explain** the difference between reactants and products in chemical reactions.

3 **Recall** what the arrow represents in a chemical equation.

4 **Explain** why it is unnecessary to write an equation for a physical change.

Apply and analyse

5 **Identify** the reactant and product in the following chemical reactions.

- **a** Iron ore is made into a steel ship.
- **b** Bread is made from flour.
- **c** Freezer bags made from polythene are manufactured from ethene.
- **d** Carbon dioxide is produced when petrol is burnt in a car engine.

Evaluate and create

6 Rusting is a common chemical reaction. **Describe** the process of rusting and write a word equation for this reaction. **Identify** the reactants and the products.

Skills builder: Planning investigations

7 Plan an investigation that explores the rate of one chemical reaction under different conditions (for example, rusting).

- **a** **Identify** the dependent variable, independent variable and any controlled variables. (THINK: What are you changing or measuring in your investigation? Which other variables might need to be controlled?)
- **b** Write a method for your investigation and draw a scientific drawing of the experimental set-up. (THINK: What is a logical order for each step in the method?



18.4 Many substances exist because of the work of scientists

In this topic you will learn that:

- new products can be developed by making or obtaining new substances from nature.



Figure 1 All these products come from petroleum.

It is easy to forget just how much we rely on manufactured products in our life. Increasingly, many substances and materials are processed (that is, changed) or manufactured before they are used. These substances – such as medicines, electronic components, composite materials in aircraft and polymers – only exist because of the work of scientists changing them from their original state to ones that you can use.

Scientists share their findings and results with the rest of the scientific community. They do this in a number of ways, such as by presenting to the scientific community at conferences and publishing articles in science journals. The reason why scientists share their ideas and collaborate with one another is to extend their understanding. Scientists can increase scientific knowledge by building on previous understanding. Scientists in the future will continue to build on this understanding.

Oil refinery

Petroleum, or crude oil, is an important product in our society. Oil is pumped from the ground and carried in pipelines or tankers to refineries, where it is separated into its components. The low-value parts of the crude oil mixture are converted into high-value products, such as petrol, diesel and materials used to produce plastics.

Many substances that we now take for granted – such as medicines, chemicals used in agriculture and construction, and plastics such as polyvinylchloride (PVC) and polythene (PE) – are made from chemical reactions with crude oil. These products are hard to make in the laboratory because they require high temperatures and some specialised conditions. A substance that you can make in the laboratory is nylon – a compound consisting of long molecules (called polymers).

Glues and adhesives

Glue was used in ancient Babylon 3500 years ago when King Nebuchadnezzar used asphalt/bitumen to hold building stones together. Later, plant gums, egg white and animal products (such as gelatin) were used for gluing paper and wood. The paints used by the masters during the Italian Renaissance were made using egg white, which helped to hold the parts of the paint mixture together.

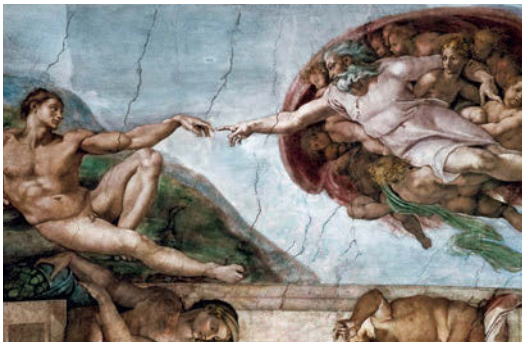


Figure 2 Older paints contained egg white to help hold the paint together.

In World War I, aircraft were made of wood. The wood was glued with casein glue (a protein in milk) and albumin (a protein in egg white).

Nowadays, many synthetic glues are used. Once shoes were made of layers of leather nailed and sewn together; now these layers are mostly glued. Glue is used to hold many things together, including the chips in chipboard and the layers in MDF board, plywood and a lot of furniture. Even the brake linings in cars are glued (bonded).

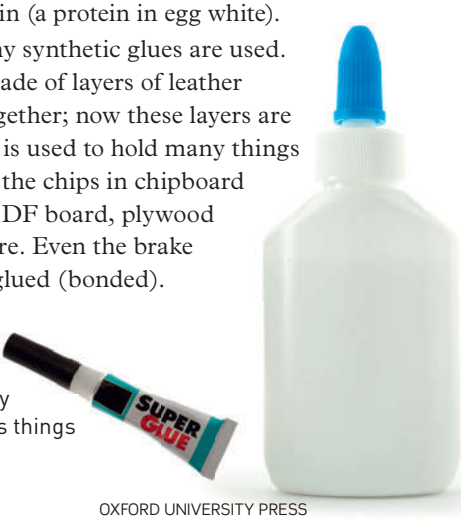


Figure 3 A glue is any substance that sticks things together.

INVESTIGATION
18.4: Making casein glue
Go to page **411**.



Figure 4 Dyes originally came from living organisms. Today they are mostly synthetic.

Dyes

Before the use of dyes, all clothes had the same colour – the off-white colour of natural fibres, raw cotton, silk and wool.

The first dye was obtained from murex whelk shells, a type of sea snail. It took 9000 shells to make enough dye for one Roman emperor's toga! Only the emperor had dyed clothes, and these were always purple. In fact, the whelk almost became extinct as a result of being hunted for its dye.

From the 17th to the 20th centuries, the soldiers in the British Army were known as 'red coats' because their uniform consisted of a red coat, which was dyed using the liquid extracted from scale insects. This red dye, cochineal, is available today in supermarkets, but it is now made synthetically.

The first synthetic (or artificial) dye was discovered accidentally in 1878 by British chemist William Perkin (1838–1907). He named his dye after its colour – mauve. Soon many other coloured dyes had been discovered and were being manufactured.

Computer printers use dyes when they print photographs. Modern inks do not fade, so the photographs last longer than photographs printed many years ago.

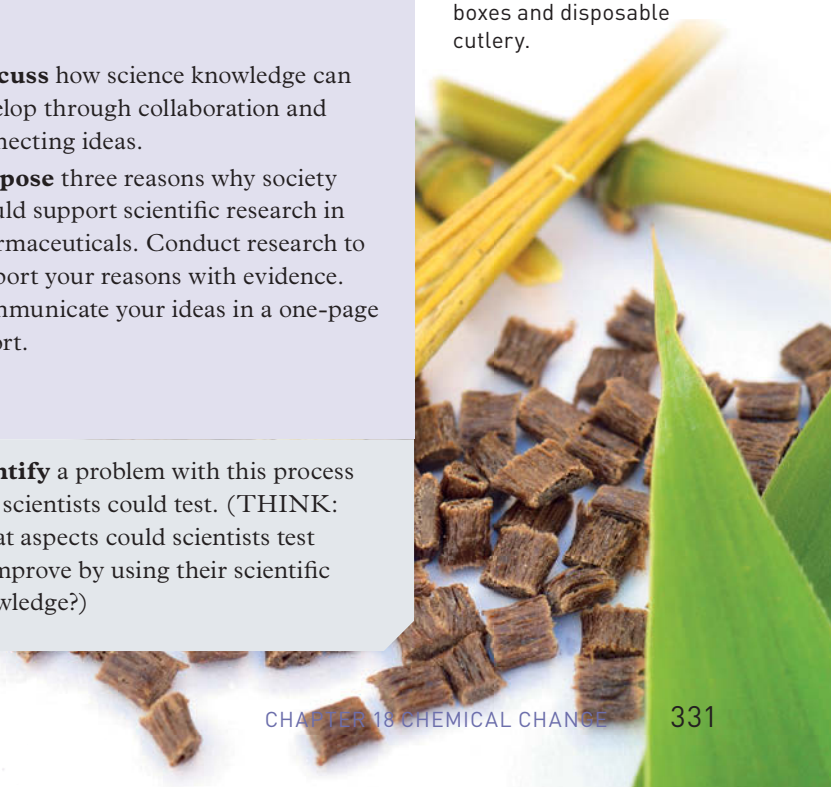
Biopolymers

Plastics are produced from a group of chemicals called polymers. Many of the plastics that we use today are manufactured from crude oils found in petroleum. There are many concerns surrounding the sustainability and environmental impacts of extracting and burning crude oil. So scientists have been researching a more environmentally friendly option: how to develop polymers from living things. These are called **biopolymers**.

One type of biopolymer, biopolyester, is synthesised from different types of bacteria, including *E. coli*. Biopolymers can also be made from plant biomass, such as agricultural products like plant crops and wood. Examples of these polymers are cellulose and rubber.

biopolymer
a polymer developed from living things

Figure 5 A biopolymer can be made from bamboo – this will be melted and moulded into biodegradable plastics such as takeaway food boxes and disposable cutlery.



Check your learning 18.4

Recall and explain

1 **Recall** the role of chemistry in purifying crude oil in an oil refinery.
2 **Describe** how chemists have improved on natural glues and adhesives.
3 **Identify** five materials that are made by chemists.

Evaluate and create

4 How do scientists build on ideas to discover or make new substances?
Discuss how science knowledge can develop through collaboration and connecting ideas.
5 **Propose** three reasons why society should support scientific research in pharmaceuticals. Conduct research to support your reasons with evidence. Communicate your ideas in a one-page report.

Skills builder: Problem solving

6 Consider the purple dye produced to colour a Roman emperor's toga. It took 9000 murek whelk shells to make enough dye for one Roman emperor's toga.
Identify a problem with this process that scientists could test. (THINK: What aspects could scientists test or improve by using their scientific knowledge?)

REVIEW

Multiple choice

1 Which of the following describes a chemical change?
- **A** Breaking glass
- **B** Burning toast
- **C** Melting ice
- **D** Mixing sand and water

2 In a chemical reaction, the new substance that is produced is called:
- **A** the chemical
- **B** the result
- **C** the product
- **D** the reactant.

3 How is a physical change different from a chemical change?
- **A** A physical change refers to rusting or cooking processes.
- **B** A physical change requires heat.
- **C** A physical change is permanent.
- **D** A physical change is reversible.

Recall and explain

4 Use the particle model to explain:
- **a** melting
- **b** freezing
- **c** sublimation
- **d** condensation.

5 **Describe** what changes might be observed during a chemical change.

6 **Explain** the difference between a physical change and a chemical change.

7 Using your knowledge of particles, **explain** why most physical changes can be reversed.

8 **Identify** four ways to speed up a chemical reaction. Use the particle model to explain why each method works.

9 **Describe** an example of a chemical change that occurs in everyday life.

10 **Explain** what happens when heat energy is applied to a substance.

11 The use of chemistry to produce new materials has affected peoples' lives in a range of ways.
- **a** **Recall** how new materials have changed the type of clothes that people wear.
- **b** **Recall** how new materials have changed the type of food that people eat.

Apply and analyse

12 In an experiment, a reaction between copper sulfate solution and iron made solid copper and an iron sulfate solution.

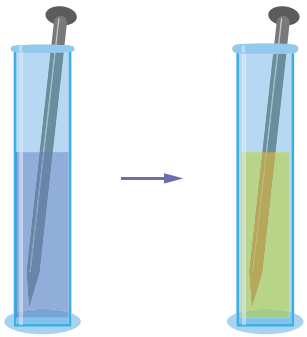


Figure 1 Reaction of copper sulfate solution and iron to make solid copper and an iron sulfate solution

- **a** Complete the following table to **summarise** the changes observed in this reaction.

Name of reactants	Description	Name of products	Description

- **b** Use the information in the table to **explain** why this is an example of a chemical change.

13 Dyes can be synthetic or natural in origin.
- **a** **Describe** one advantage and one disadvantage of using natural dyes.
- **b** **Describe** one advantage and one disadvantage of using synthetic dyes.



Figure 2 Indigo dye

14 **Identify** a chemical change that may be harmful to the environment if it is allowed to occur in an uncontrolled way.

15 The following are descriptions of interactions that occur around us in our daily lives. **Describe** what the products of these interactions might be, and **explain** whether you think the changes described are useful or harmful.

- **a** A bike is left out in the rain so that parts of the bike that are made of steel are in contact with water for a few hours.
- **b** A barbecue fuelled by propane gas is turned on.
- **c** A hairdresser adds bleach to someone's hair.

16 Many buildings in the Sydney CBD are made from limestone (see Figure 3). **Explain** why the limestone is slowly being destroyed over time and needs to be replaced.



Figure 3 Many old buildings are made from limestone.

Evaluate and create

17 Think about what you do on a daily basis, including eating, washing, travelling, working and playing. **Discuss** how these activities would be different if you were only able to use natural materials.

18 An environmental action group wanted to ban the use of chemicals in your school. Do one of the following:

- **a** Write a letter to your school principal explaining why you think this would be a good idea.
- **b** Write a letter to the leader of the environmental group explaining why you think this is a bad idea.

19 Acid rain is problematic and can cause a lot of damage to both our society and the environment. **Devise** a poster or an information brochure that describes some of these problems and **identify** some ways that we can reduce acid rain.

20 **Evaluate** the use of plant-based plastics as a replacement for traditional plastics used for disposable items such as plastic bags, take-away food containers and packaging.

Critical thinking

21 An empty carton of milk is flattened and then cut up into pieces. Is this a physical change or a chemical change? **Justify** your response.

22 Think about a candle while it is burning.

- **a** Is this a physical or chemical change?
- **b** What happens to the wax?



Figure 4 What happens to the wax when a candle is burning?

Going further

23 Substances can change when they interact with one another. In each of the following situations, a change is described. For each change, **describe** the interactions that have caused the change to occur. The first one has been done for you.

- **a** Glue makes a bond between two pieces of wood.
  Possible answer: The glue interacts with the oxygen in the air, which causes it to set hard, which joins the two pieces of wood together.
- **b** Sugar turns into caramel.
- **c** Charcoal burns in air to form carbon dioxide gas.
- **d** Starch is digested in our stomach to form simple sugars, such as glucose.
- **e** A loaf of bread rises in an oven as carbon dioxide gas is produced.

24 If all other conditions were the same, how rapidly would a large rock deteriorate compared with broken-up rocks of the same mass?

Research

25 Choose one of the following topics for a research project. Some questions have been included to help you begin your research, but you should add more questions that you want to investigate. Present your findings in a format that best fits the information you have found and understandings you have formed.

» Magic or chemistry?

Magicians use a range of tricks to deceive their audience into thinking magic is real. Some of these tricks use chemical reactions. What sorts of chemical reactions could be used in tricks by magicians? What sorts of physical changes could be used? How does the 'magic' happen?

» Respiration

Respiration is a chemical process that occurs in our body and is essential for our survival. What are the reactants used in respiration? What are the products? Where in our bodies does respiration occur? Why is respiration such an important process?

» Explosives

The history of the development of explosives is fascinating. Who discovered them? When were explosives first used and how do they work? What are the main chemicals used and what types are there? What part did Alfred Nobel play in the history of explosives?

» Barbecue fuels

Most home barbecues burn LPG as the fuel. This gas can be bought at hardware and camping stores in cylinders. What does LPG stand for? What chemicals are present in LPG? What are the advantages of gas barbecues over solid fuel barbecues? What safety precautions must be followed when storing LPG cylinders?

Reflect

Now that you've completed this chapter, reflect on your ability to do the following:

	I can do this.	I can't do this yet.
Identify when a chemical change is taking place by observing a change in temperature, the appearance of new substances or the disappearance of an original substance.	☐	☐ Go to page 326–327.
Demonstrate that a chemical change involves substances reacting to form new substances.	☐	☐ Go to page 326–329.
Investigate some examples of chemical change that occur in everyday life, e.g. photosynthesis, respiration and chemical weathering	☐	☐ Go to page 328–329.
Compare physical and chemical changes in terms of the arrangement of particles and reversibility of the process.	☐	☐ Go to page 324–327.
Propose reasons why society should support scientific research, e.g. in the development of new pharmaceuticals and polymers.	☐	☐ Go to page 330–331.
Describe, using examples, how science knowledge can develop through collaboration and connecting ideas across the disciplines of science, e.g. Making or obtaining new substances from earth's spheres.	☐	☐ Go to page 330–331.

Source: NSW Science Years 7–10 Syllabus © NSW Education Standards Authority for and on behalf of the Crown in right of the State of New South Wales, 2018.



STUDENT RESEARCH PROJECT

How do I complete my student research project?

19

Have you ever wondered ...

- How do I come up with a research question?
- Where do I find information about my topic?
- How do I present my results?

SCIENCE SKILLS

- In Stage 4, you will conduct your own research project. This gives you the opportunity to see your own science skills in action and investigate something interesting to you!
- This chapter is here to help you plan, conduct and reflect on your research project.
- The student research project is a little bit different at every school. So if you are ever in doubt about what you are supposed to do, remember to ask your teacher.

19.1 Beginning your research project

In this topic you will learn that:

- you should choose a topic that interests you.

The student research project requires careful planning before you begin. You will need to find a topic that interests you, which you can test scientifically. You will then need to conduct background research and plan your experiments so that they can be conducted scientifically and safely.

Choosing a topic

Choosing a topic to research can be the hardest part of the whole student research project.

If you need to develop your own topic and question, the first thing to think about is what interests you. You will spend a lot of time on this project, so try to choose something that you are genuinely curious about. More importantly, your topic needs to be something that can be tested scientifically.

Your research project could involve a problem that:

- tests a claim or a device; for example, does X brand of battery last three times longer than other batteries?
- designs and conducts an experiment; for example, what recipe for antibacterial soap kills the most germs?)

If you're still having trouble thinking of anything, you could also search the internet for inspiration.

Using a project topic checklist

Once you've identified a topic for your project, consider the using a checklist like the one in Table 1. If you answer 'No' to any of the questions in the checklist, you may need to speak with your teacher or group.

Table 1 A project topic checklist

Topic checklist	Yes	No
Does this topic interest me?		
Can I write a scientific research question?		
Can I test this safely and ethically?		
Would this project be achievable in terms of time and equipment?		
Is this project the right level of difficulty for Stage 4?		

Brainstorming

Once you have a general idea of a topic that interests you (for example, sport or the local environment), you can begin brainstorming. Brainstorming is a useful tool for generating lots of ideas. It does not matter if the ideas are good or not: you just want to write down as many things as you can think of. One idea can lead to another. Figure 1 shows an example of how you can use concept maps to visualise your brainstorm.

You can use brainstorming for many stages in the research project. For example, you could use a concept map to help you to identify all the variables in your experiment and how you might control these.

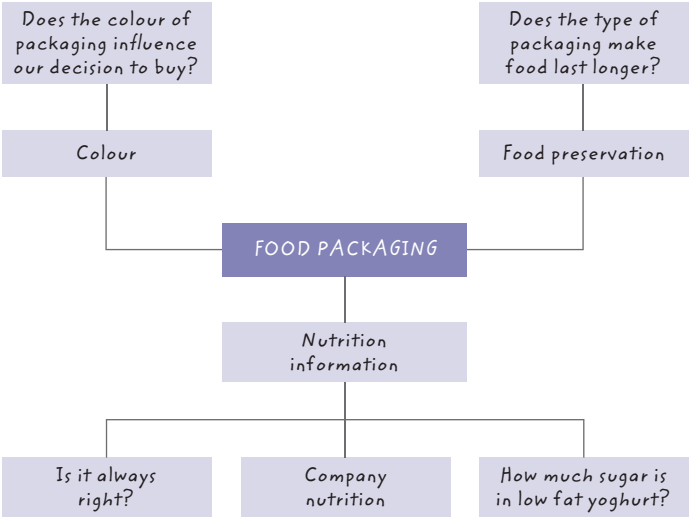


Figure 1 A brainstorm on food packaging as a concept map

Practising key science skills

The student research project is an opportunity for you to put your science skills to the test.

Before you conduct your investigation, you will need to first plan everything out. Throughout this process, you will be required to demonstrate your skills at:

- questioning and predicting
- planning investigations
- conducting investigations
- problem-solving
- communicating.

These key skills are covered in chapter 1. You can use this chapter as another resource to help you plan and conduct your student research project. If you haven't already read it, you might find some useful information in there.

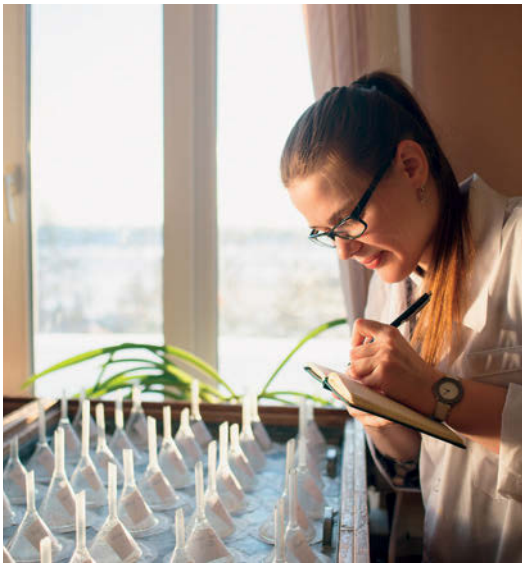


Figure 2 Setting up a logbook and taking detailed notes will help you to remember everything when it comes time to communicating your project.

Set up your logbook

A logbook will help you to record the process of your student research project. This is important so that you can remember what you have done when it comes time to write your report at the end.

You should start using your logbook when you begin your project. Include your brainstorming and note taking in your logbook so that you can reflect on this all at the end of the process.

More information on what to include in a logbook and how they can be set up can be found in chapter 1.



Figure 3 What do you observe in these three photos?

Check your learning 19.1

Apply and analyse

1. Examine one of the images in Figure 3. Brainstorm what you observe and possible research topics that emerge from these observations.
2. Using the information in chapter 1 as a guide, set up your own logbook for the research project.
3. Hanna likes to grow different types of indoor plants, but one species of plant keeps dying in her house. **Propose** a research topic for Hanna.
4. Hamza would like to test how long it takes for plastic bags that are advertised as 'compostable' to break down. **Suggest** why this may be difficult to test for the student research project.

19.2 Conducting background research

In this topic you will learn that:

- background research can come from many sources, including books, people and internet searches
- it is important to evaluate the information to ensure it is reliable.

Where do you look for information when you need to know something? Search engines like Google are a good start, but they're not the only places we can find out more about a research topic. Other places to find information include:

- your school or local library – you can ask the librarian to help you find the right books or search via the library catalogue
- people – you can interview people to find out more about a topic, especially if they are scientists or experts on a topic
- organisations – some companies are very happy to help you find out more about their industry
- magazines, journals and pamphlets – other types of printed texts can be a good source of information too.

A good student research project should use a variety of resources. If you are going to speak to a person or a company as part of your research, remember to be polite.

Check the source is reliable

Once you have found your information, you need to evaluate the source of information to make sure it is trustworthy. But how can you tell if the information you found is reliable? One good test is to use the questions in Table 1.

Table 1 Questions to consider when evaluating sources

Is the source current?	When was the information first published? If it was written 200 years ago, or even 20 years ago, it's possible it may be out of date.
Is the source relevant?	How important is it to know this information for your research project? Does it help you to answer your question? If not, it may be better to leave this source alone.
Who wrote this source?	Is the author an expert? Websites that end in .org, .edu and .gov are often more reliable.
Is this source accurate?	Is the information supported by evidence?
Why does this source exist?	What is the purpose of this information? Is it trying to persuade or educate? Could it have been written for political or personal reasons?

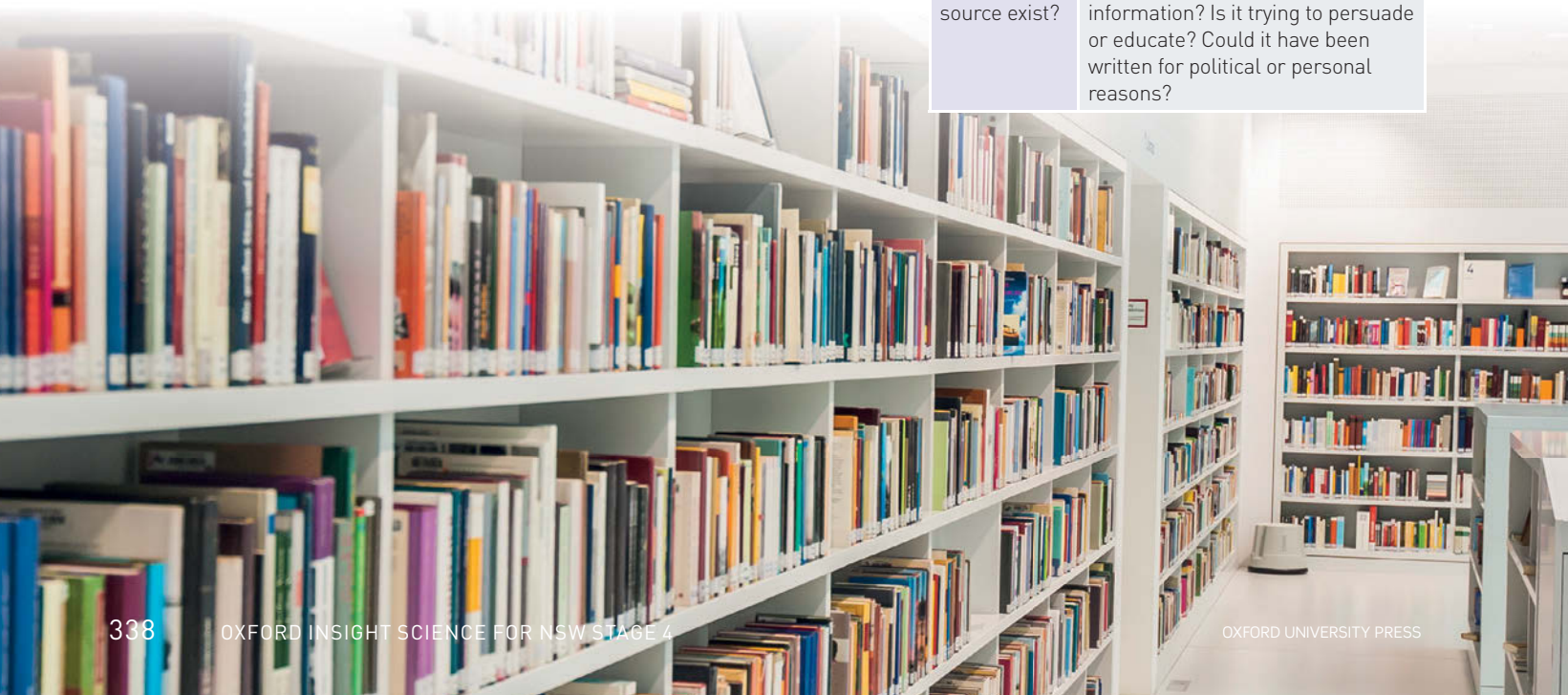


Figure 1 Don't forget about the library when you are conducting background research. Books, magazines and journals can be an excellent source of reliable information.

Take notes

As you are reading, remember to take notes about ideas that are relevant to your topic. If you think something will be important to your research project, write it down, noting where you found it and who authored it. If you need to come back to the source for another look, you want to be able to find it again easily. This is the kind of information that you should include in your logbook.



Figure 2 Take notes when you are researching so you can easily recall information later.

Reference

If you want to refer to someone else's ideas in your project, you need to reference where they have come from. It is crucial that you do not take credit for ideas or work that are not your own. If you don't credit other people's ideas or work, this is called plagiarism, which is considered highly unethical in the science community.

To avoid plagiarism, you need to let people know if an idea has come from somewhere else. To do this, scientists provide a list of sources they have referred to in their project called a reference list.

There are different ways to format each reference in a bibliography, but it usually includes such information as the author's name, year the information was published and where you found it. Your teacher will let you know if they expect you to use a specific format for your references.

Sentences such as the following can also help you to acknowledge your sources:

- 'According to a report published by the CSIRO …'
- 'Dr Smith discovered in 2019 that …'
- 'A study by researchers at UNSW found …'

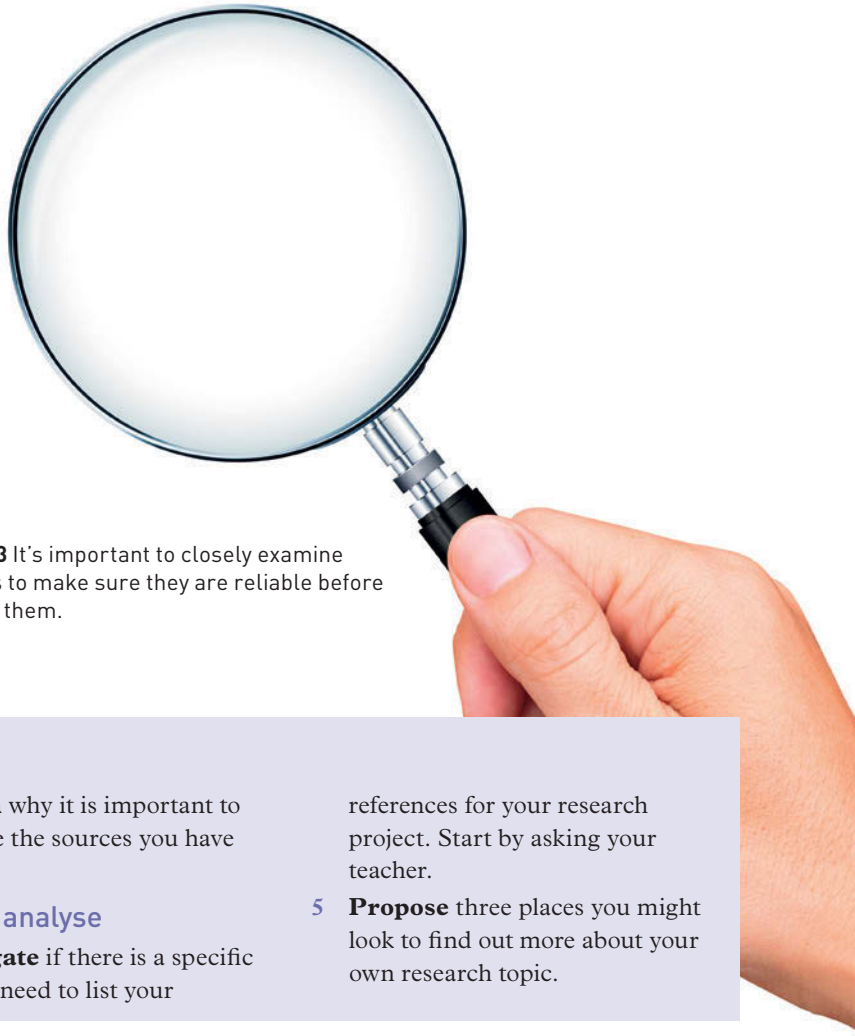


Figure 3 It's important to closely examine sources to make sure they are reliable before you use them.

Check your learning 19.2

Recall and explain

1 Besides the internet, **identify** three places that you can find information.

2 **Recall** three questions you can ask to evaluate a source.

3 **Explain** why it is important to reference the sources you have used.

Apply and analyse

4 **Investigate** if there is a specific way you need to list your references for your research project. Start by asking your teacher.

5 **Propose** three places you might look to find out more about your own research topic.

19.3 Conducting safe research

In this topic you will learn that:

- a risk assessment must be completed for all experiments
- a safety data sheet (SDS) is required if any chemicals or substances are used.



Figure 1 Science hazard symbols

The most important part of any experiment is safety. In chapter 1, we learnt about rules for lab safety and what you should do if you or someone else gets hurt. But staying safe in the lab is not just about following rules: it's also about behaving sensibly in the lab around dangerous equipment and chemicals. If you want to complete your student research project successfully, you will need to consider safety as one of your highest priorities.

For your student research project, you may be required to complete a risk assessment and safety data sheet before you conduct any experiment.

Complete a risk assessment

A risk assessment is a register (or record) of all the possible hazards involved in an experiment. It helps to identify all the risks to human safety or the environment. It then assesses the likelihood of these risks and outlines how the risks can be controlled.

A risk assessment typically includes:

- a description of the procedure
- the equipment required
- a list of hazardous chemicals required and their GHS classification
- a list of non-hazardous substances required
- a description of how chemicals will be controlled
- other possible hazards and risks
- protective measures, such as lab coat, safety glasses and fume cupboard
- a description of clean-up and how the chemicals will be safely disposed of.

You can download a risk assessment template for your project on your obook.

Complete a safety data sheet

If you plan on using any substances or chemicals, you will need a safety data sheet (SDS). An SDS provides scientists with information on how to use a particular substance. It can also help us to understand more about how the chemical is used during an experiment.

Consider the example SDS in Figure 1. It describes:

- the various names of the chemical
- the contact details of the manufacturer
- the hazard level of the chemical
- usage instructions and restrictions
- protective measures
- the physical and chemical properties of the chemical
- what to do in case of a spill
- fire-fighting measures
- how to dispose of the chemical safely
- how to transport the chemical.

There is an SDS available for every chemical sold in Australia. You can find these online.

Check your learning 19.3

Recall and explain

1. **Explain** why it is important to conduct a risk assessment.
2. When would you need to provide a safety data sheet?

Apply and analyse

3. Download the risk assessment form from your obook and fill out the potential risks and solutions for your research project.

MATERIAL SAFETY DATA SHEET

Sodium Chloride: Hazardous chemical

Section 1 - Chemical Product and Company Identification	
MSDS name:	Sodium Chloride
Synonyms:	Common salt; Halite; Rock salt; Saline; Salt; Sea salt; Table salt.
Company identification:	Chemical company
Section 2 - Hazards Identification	
Eye and skin:	May cause eye irritation.
Ingestion:	Ingestion of large amounts may cause gastrointestinal irritation. Ingestion of large amounts may cause nausea and vomiting, rigidity or convulsions.
Inhalation:	May cause respiratory tract irritation.
Section 3 - Handling and Storage	
Handling:	Use with adequate ventilation. Minimise dust generation and accumulation. Avoid contact with eyes, skin, and clothing. Keep container tightly closed. Store in a cool, dry, well-ventilated area away from incompatible substances. Store protected from moisture.
Section 4 - Exposure Controls, Personal Protection	
Engineering controls:	Good general ventilation should be used.
Personal protective equipment	
Eyes:	Wear safety glasses with side shields.
Skin:	Wear appropriate gloves to prevent skin exposure.
Clothing:	Wear appropriate protective clothing to minimise contact with skin.
Section 5 - First Aid Measures	
Eyes:	Flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical aid.
Skin:	Flush skin with plenty of soap and water for at least 15 minutes while removing contaminated clothing and shoes. Get medical aid if irritation develops or persists. Wash clothing before reuse.
Ingestion:	If victim is conscious and alert, give 2-4 cupsful water. Get medical aid. Wash mouth out with water.
Inhalation:	Remove from exposure to fresh air immediately. If breathing is difficult, give oxygen. Get medical aid if cough or other symptoms appear.
Section 6 - Physical and Chemical Properties	
Physical state:	Solid
Appearance:	Colourless or white
Odour:	Odourless
Boiling point:	1413 deg C
Freezing/melting point:	801 deg C
Solubility:	Soluble
Specific gravity/density:	2.165
Molecular formula:	NaCl
Molecular weight:	58
Section 7 - Accidental Release Measures	
Spills/leaks:	Vacuum or sweep up material and place into a suitable disposal container. Clean up spills immediately, observing precautions in the Protective Equipment section. Avoid generating dusty conditions. Provide ventilation.
Section 8 - Fire Fighting Measures	
General information:	Water runoff can cause environmental damage. Collect water used to fight fire. Wear appropriate protective clothing to prevent contact with skin and eyes. Wear a self-contained breathing apparatus (SCBA) to prevent contact with thermal decomposition products. Substance is noncombustible.

Figure 2 Example of an SDS from a manufacturer or certified provider

19.4 Working in groups

In this topic you will learn that:

- it helps to set expectations by making sure everyone has a role and something to contribute
- group decision-making strategies can make sure everyone's ideas are considered
- creating a project timeline and setting goals will help to keep a project on track.

Teamwork is an important part of scientific discovery. As you would have learnt throughout Stage 4, a lot of our scientific knowledge has been built by scientists sharing their understanding and working together.

Working in groups for your research project can have many benefits. More people means more brain power and creativity for solving problems. Working well in teams is also an important skill for many career paths.

But teamwork also has its challenges. For example, how do you make sure that every voice in the group is heard? How do you make group decisions if you don't all agree? What happens if someone isn't doing their fair share of the work? What happens if you're not all friends?

In this topic, we will explore a few strategies you can use if you're working in a group for the student research project.



Figure 1 Everyone in a group has a part to play in the student research project.

Set roles and responsibilities

A good way to make sure that every member of your group is included is to ensure they all have a specific role. That way everyone is contributing and can have an opportunity to lead a task. Table 1 outlines some roles and responsibilities you might like to assign in your group.

These roles might not cover all the work that needs to be done in the research project, and they may not suit the number of people in your group. In this case, discuss how you will divide the work in your group to make sure everyone plays an equal role.

Table 1 Group roles and responsibilities.

Role	Example responsibilities
The facilitator, or leader	> Makes sure everyone's voice is heard during discussions and decisions > Keeps the group on track to finish on time > Makes sure the group is getting along
The recorder	> Writes down decisions > Writes logbook entries > Records observations from experiments
The researcher	> Leads background research > Compiles a list of references
The materials manager	> Manages any equipment needed > Coordinates the risk assessment and SDS
The communicator	> Summarises the group's conclusion > Coordinates information for the final report

Make decisions as a group

Making decisions can often be a source of conflict in groups. Sometimes the most confident people in the group can dominate discussion and make decisions. So what about the team members who might be shy or less confident? If only a few people have a chance to speak, you could find yourself missing out on some good ideas for the group.

Table 2 outlines a list of strategies for decision-making to help keep everyone included. You might like to try more than one of these as you go. Everyone learns and works differently. Depending on your group, you might like to try some of these and not others.

Evaluating the options

If you've brainstormed a range of options and you have to decide between more than one good option, it can be helpful to analyse the advantages and disadvantages. Using a 'pro/con' list (see Table 3) or 'PMI table' can help you to work out the best decision for your group. It can also help your whole team to explain and share why they may be in favour of or against a certain idea.

Remember to be kind

One of the most important things about group work is communication. Is everyone being listened to? If you have a problem, have you told anyone about it? Remember: communicating with kindness will always get you further than communicating with frustration. If you want someone to listen to you, speak to them politely and make sure you listen to them in return.



Figure 2 Identify the pros (positives) and cons (negatives) of an option. If the cons outweigh the pros, it might not be a good idea.

Table 2 Group decision-making strategies

Decision-making strategy	How does it work?
Take a vote	The group discusses the advantages and disadvantages for each option. The group then votes, and the option that receives the majority of votes wins.
Process of elimination	The group discusses the advantages and disadvantages for each option. The group votes for each of the options they do not want. An option is removed each round of voting until only one option remains.
Negotiation	The group discusses the advantages and disadvantages for each option until everyone agrees on one option.
Follow the leader	Someone from the group is elected to lead the discussion about the decision. Once everyone has had their opinions heard, the leader makes the final decision. The leader must make a decision that represents the group's wishes, but the group must also respect the decision of the leader.
The best of both worlds	The group assesses each option and tries to find a way to incorporate the best of both options into one new combined option.
Block or not	The group discusses the advantages and disadvantages of each decision. They then vote for each option on a scale of 1–5. Voting 1 means they strongly support the decision, whereas voting 5 means they want to block the decision. If an option receives only numbers 1–4, it will not be blocked. If an option receives a 5, it is blocked.

Table 3 A list of pros and cons can help your group to make a decision about an idea.

Idea: Using a digital logbook	
Pros	**Cons**
> Easier to share and work on individually > Will be neater to read > Saves having to retype information later for the report	> Not able to have a computer or tablet present while conducting the experiment > Needs to be backed up > Teacher needs to collect the logbook at the end of every class to check

Check your learning 19.4

Recall and explain

1 **Describe** two strategies for making a group decision.

Apply and analyse

2 How would you divide the work of the research project if there were four people in your group?

3 **Explain** the decision-making strategy that you would prefer to use in groups.

4 Consider the responsibilities involved for your research project. Which would you like to be responsible for?

19.5* Managing your time

In this topic you will learn that:

- you will need to work carefully to finish your student research project on time.

It may feel like there is a lot of time to complete the student research project, but it goes by very quickly.

Create a project timeline

How many weeks do you have to complete your student research project? Your teacher will give you a due date. You can use this due date to work out how much time you have from now until then.

Table 1 shows an example of how you can map out your time to plan when you will perform each task. This will help you to stay on track and make sure you finish on time. The example here gives you eight weeks to complete your project, but you may have more or less time than this depending on your school.

Table 1 A sample timeline for an eight-week student research project

Week 1	Choose your topic and to know your group
Week 2	Conduct background research
Week 3	Design your experiment and discuss design with teacher
Week 4	Organise equipment for next week and organise risk assessment
Week 5	Conduct experiment
Week 6	Reflect on the experiment and write report
Week 7	Edit report
Week 8	Present or submit

Set goals for each period

Once you have a timeline, the trick is sticking to it! If you want to be even more organised, you could break your schedule down to outline the tasks you want to achieve in each period of the week. You could set these goals at the beginning of each period, or at the beginning of the week.

Setting goals can help make sure you get to everything you need to before you run out of time. If you find you are not making any progress on a task, stop what you are doing and move on to the next task. You can come back to this problem later. Sometimes a bit of time away from a task can help give you a break and gain the perspective you need.

It's important to avoid spending too much time on one task. For example, if your group has been spending 40 minutes discussing how to make your project a fair test, you might run out of time for other tasks.



Figure 2 Setting goals

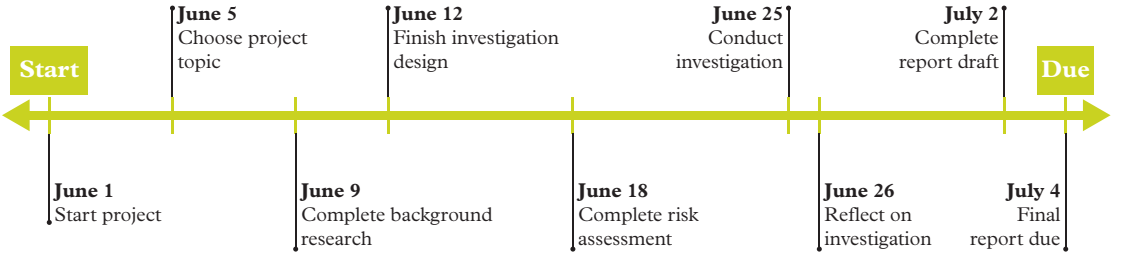


Figure 1 A research project timeline



Figure 3 Keep an eye on the time when you're planning and conducting your student research project.

- Make sure you know in what order you have to complete each task. For example, there's no point conducting a risk assessment until you know what materials you are using for your investigation.
- Try not to get distracted by ideas that aren't going to help you complete your project. There's always time to investigate other things later.
- Don't panic when things go wrong. If your plans don't work out, or something goes wrong, stay calm and ask for help.
- Make sure you know what the rest of your group is working on so that you don't end up completing the same tasks.

Tips for staying on track

Everyone works differently, so it can help to try a few different ways of organising yourself and figure out what works best for you. For example, you might like to do one or more of the following:

- Write a to-do list for each lesson.
- Delegate tasks to everyone in your group so that everyone is making the best use of time.
- Set time limits for each task so that you don't end up spending an hour on something that should only take 10 minutes.
- Take on one task at a time – thinking about the whole project at once can be overwhelming.



Figure 4 Writing a 'to do' list for each lesson can help you to keep track of what needs to be done.

Check your learning 19.5

Apply and analyse

1. **Identify** the due dates for your research project.
2. **Consider** the research project ahead of you. **Identify** all the individual tasks that need to be completed.

Evaluate and create

3. **Construct** your own schedule for your research project.
4. **Consider** other ways that you like to manage your time. Is there anything else you could do to manage your time during your student research project?
5. **Consider** what might make it hard for you to manage your time during the research project. For example, do you spend a lot of time talking in class, or have you chosen a very difficult research topic? Brainstorm some ways you could overcome this problem.
6. Reflect on how you normally manage your time. Do you set reminders on your phone? Do you write due dates in your diary? Which time management techniques will you use (or improve) to make sure you finish on time?

19.6 Communicating your research

In this topic you will learn that:

- scientific writing should be clear, objective and easy for the reader to follow
- scientific research can be communicated in many ways, including written reports, posters and oral presentations.

In science, the way you write should be as clear as possible, concise (kept short) and focused on evidence, not opinion. Writing scientifically can be different from the writing you do in English or Humanities classes.

Write scientifically

Tips for scientific writing include the following:

- Avoid complicated and long sentences. Keep it to one idea per sentence.
- Always write your method in the past tense. For example, 'The beaker was placed over the Bunsen burner and heated for 30 seconds'.
- Avoid personal statements such as 'I observed' or 'We noticed'. Write in the third person.
- Be objective. Report your findings supported by evidence, and not feelings about them.
- Avoid subjective statements. For example, avoid sentences like the following: 'The contents of the test tube transformed into a beautiful shade of blue when placed over the roaring flame'. A better scientific observation would be: 'The substance in the test tube turned blue when heated over the Bunsen burner for 10 seconds'.





Figure 1 a How would you write or speak about your project if you were talking to a group of scientists? **b** What about if you were communicating with a group of primary school children?

Remember your audience

Who will be reading or listening to your final report? It is unlikely they will know or remember the specific details of your project. When communicating your research, you should write as if you are speaking to someone who knows nothing about your project. You will need to help them to understand your topic, your hypothesis and a full step-by-step description of your materials and method.

Think about this: could a scientist on the other side of the world read your report and be able to replicate your investigation exactly? If the answer is 'No', you need to think about how you can make your report clearer.

Use visuals

You don't just have to write paragraphs to communicate your ideas. Sometimes visual aids can be very helpful to share your observations, experimental set-up or data. This can help people to understand your point quickly and easily. For example, you can use:

- photos
- diagrams
- audio or video recordings
- graphs
- tables.

Raw data can be difficult to read. As you will have learnt in chapter 1, you are encouraged to process the data you collect into more readable forms such as tables and graphs to highlight your findings and make your final report easier to read.

Choose a presentation format

The first thing you should think about when choosing how to present your project is the criteria. What criteria are you being marked on and how can you best demonstrate that you have met these? The criteria will vary between schools, so check the resources your teacher has provided for you or, if in doubt – ask!

In chapter 1, we discussed what you should include in a written report. But what if you want to do something different?

Poster presentation

Posters are a popular form of communication for scientists. They allow for lots of information to be communicated quickly. For example, a scientist may want to share their findings at a conference with other scientists, but nobody has the time to read a full report.

A typical poster structure is shown in Figure 2. Similar to a written report, a poster demonstrates all the key information of the research project, including an introduction, the research question, a hypothesis, method, results and conclusion.

Oral presentation

If you are going to deliver your research project as an oral presentation, remember:

- Try to speak clearly and slowly so that everyone can understand what you are saying.
- Don't read from your slides. If you are using a PowerPoint (or similar), your slides should add something – such as a visual photo or graph – rather than just repeating what you are saying.
- Structure your speech. You will still need to have an introduction, analysis of results, discussion and conclusion, just like a written report.

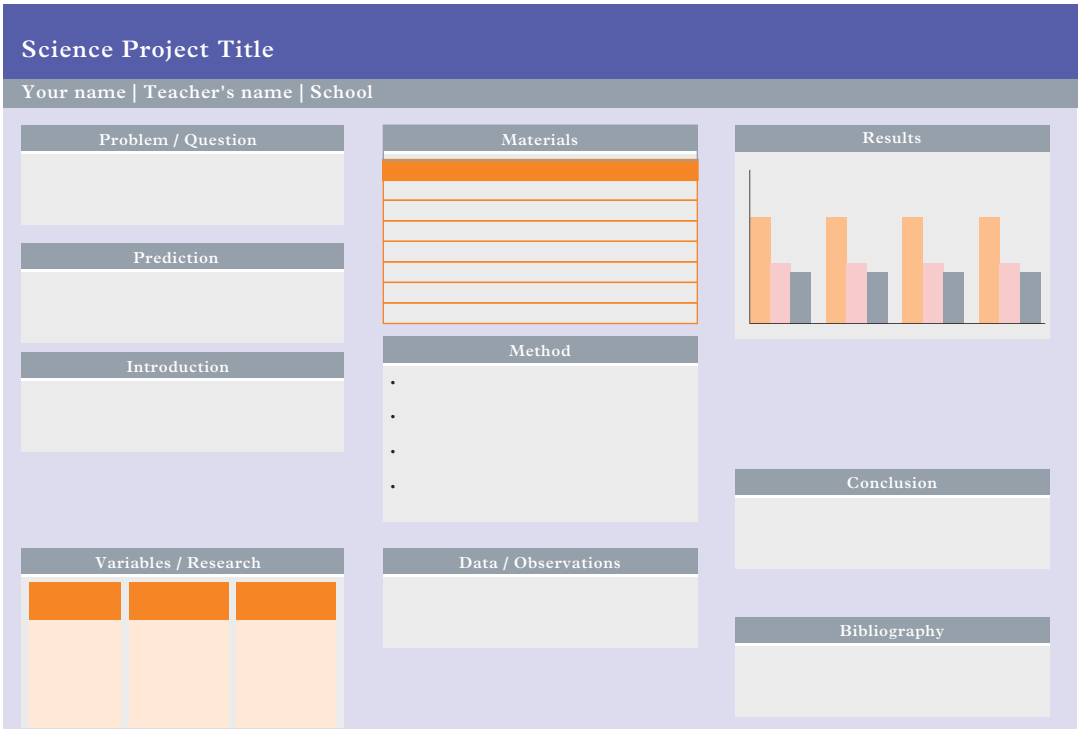


Figure 2 A suggested format for poster presentations

Check your learning 19.6

Recall and explain

1 **Explain** three key features of scientific writing and why they are important.

2 **Identify** what a poster, written report and oral presentation all have in common.

Apply and analyse

3 A scientist in Sweden is reading a student research project report and would like to replicate the experiment. Unfortunately, she can't work out the experiment set-up from the description. **Suggest** two ways the report could be improved so that it would be easier to replicate.

Evaluate and create

4 Which presentation format are you most likely to use for your own student research project? **Justify** your response. What factors influenced your decision?

*YOUR STUDENT RESEARCH PROJECT

You can use these questions to help guide you through your project, or your teacher might provide another resource suited to the specific requirements of your school. These questions can also be used as a prompt for what to include in your logbook.

Plan

Complete the following questions to make sure you have properly planned everything before you conduct your research project.

1 **Identify** the key details of your investigation.

Project topic	
Question	
Aim	
Prediction	

2 **Identify** your variables.

Independent variable	
Dependent variable	
Controlled variables	

3 **Identify** the materials you will need.

Materials	

4 **Construct** a diagram that shows your experimental set-up (see chapter 1 for help with drawing scientific diagrams).

5 **Explain** how you will ensure this is a fair test (see chapter 1 for help with planning a fair test).

6 **Identify** the safety risks of conducting your research project.

Risk/s	Description	Likelihood	Consequences	Strategy to reduce the risk

7 Complete a Safety Data Sheet (SDS).

8 **Assess** the ethics of your research project.

9 **Describe** the background research you have conducted to assist your planning. **Identify** the sources you used.

10 **Identify** the method for your research project, step by step.

Conduct

The following set of questions are designed to get you thinking about how you will conduct your research project.

11 What strategies are you using for working in a group or alone?

12 What kind of data is collected during this project? How is it recorded?

Analyse

13 **Identify** the best way to collate and present this data so that it can be analysed.

14 Analyse the data you have collected. Are there any trends, patterns or answers emerging? If not, **account** for why not.

15 **Identify** the relationship between your independent and dependent variables.

16 Using your scientific understanding of the topic, **explain** your results.

17 What is your conclusion for this research project? Consider your original prediction. How does it **compare** with your results?

Reflect

Once you have completed your research project, think about the following questions. (Remember: It isn't important to prove your prediction was correct. Sometimes scientists can learn more by discovering why they were incorrect.)

18 Do you feel like you understand more about your topic now? Were you able to answer your question?

19 Was your original prediction correct? What were you right about and what were you wrong about?

20 How effective was your planning? Is there anything you would do differently?

21 What errors did you make during your investigation? How would you change your investigation to reduce these?

22 Did you conduct your investigation safely? Is there anything you could do to make it safer?

23 Are you confident in your conclusion? Did anything surprise you?

24 What is your biggest take-away from conducting this investigation?



INVESTIGATIONS

20

SCIENCE LAB RULES

Being safe in the lab is essential to keep you and others from getting hurt. Whenever you are in the lab, you must always follow the rules below.

DO:

- wear a lab coat for practical work
- keep your workbooks and paper away from heating equipment, chemicals and flames
- tie long hair back whenever you do an experiment
- wear safety glasses while mixing or heating substances
- tell your teacher immediately if you cut or burn yourself
- tell your teacher immediately if you break any glassware or spill chemicals
- wash your hands after any experiments
- listen to and follow the teacher's instructions
- wear gloves when your teacher instructs you to.

DON'T:

- run in a laboratory
- push others or behave roughly in a laboratory
- eat in a laboratory
- drink from glassware or laboratory taps
- look down into a container or point it at a neighbour when heating or mixing chemicals
- smell gases or mixtures of chemicals directly; instead, waft them near your nose and only when instructed
- mix chemicals at random
- put matches, paper or other substances down the sink
- carry large bottles by the neck
- enter a preparation room without your teacher's permission.

1.1 Observation versus inference

SKILLS LAB

How good are you at making observations? Do you confuse observations with inferences? There are many things you can observe.

1 Draw up a table with two columns, one for observations and one for inferences.
2 Examine Figure 1, which is a drawing of a crime scene. Write six observations from the crime scene.
3 Write down three inferences you can make from your observations.



Figure 1 What do you observe about this crime scene?

1.2 Controlling an experiment

SKILLS LAB

Aim

To determine factors that affect the distance a balloon rocket will travel.

Risk assessment
1.2 Controlling an experiment

Lab tech notes
1.2 Controlling an experiment

What to do

1 Choose one of the following questions to investigate.
   - What if the balloon was blown up more?
   - What if the string had less friction?
   - What if the string had more friction?
   - What if the straw was shorter?

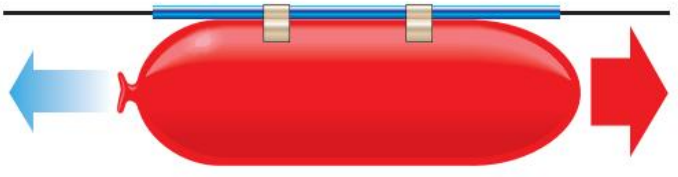


Figure 1 Determining the distance a balloon rocket travels

2 Now, follow these steps.
   - Write a hypothesis for your inquiry.
   - Which *independent* variable will you change from the first method?
   - Which *dependent* variable will you measure/observe?
   - Which variables will you need to control to ensure a fair test?
   - How will you control them?
   - Test your hypothesis. Repeat your test at least three times to make sure your results are reliable.

Results

Record your results in a table. Include units for all measurements.

Discussion

1 Was your hypothesis supported? Use evidence from your results to support your answer.
2 Write a summary of your results.

1.4 Using a Bunsen burner

SKILLS LAB

Aim

To become familiar with using a Bunsen burner.

Risk assessment
1.4 Using a Bunsen burner

Lab tech notes
1.4 Using a Bunsen burner

CAUTION! Make sure you are wearing safety goggles and a lab coat.
Remember to keep your hand below the flame.
You will be sketching in your notebook during this experiment. Keep it well away from the Bunsen burner (on a nearby bench or further up the bench).
The porcelain you heat will remain very hot for a long time. Do not pick it up with your fingers: use tongs.

What you need

- Bunsen burner
- Heatproof mat
- Matches
- Notebook
- Coloured pencils
- Grey pencil
- Metal tongs
- 2 pieces of white ceramic or porcelain

What to do

1 Place the Bunsen burner on the heatproof mat.



Figure 1 A Bunsen burner on a heatproof mat

2 Connect the rubber hosing firmly to the gas tap.



Figure 2 Connecting the rubber hosing to the gas tap

3 Close the air hole by turning the collar.



Figure 3 Closing the Bunsen burner's air hole

4 Light a match and place it just above the top of the barrel, with your hand below the flame.



Figure 4 Lighting the Bunsen burner

5 Open the gas tap fully.
6 Change the flame to a blue flame by opening the air hole on the collar. (Sometimes you can't see a blue flame. Be careful not to presume there is no flame.)
7 Write down and draw what happens to the flame when the hole is closed, half open and fully open.
8 Close the collar so that a yellow flame is produced.
9 Using tongs, hold a piece of porcelain in the top of the yellow flame for 1 minute. Place the hot porcelain on the heatproof mat when you have finished. Describe what happens to the porcelain and draw it.
10 Hold the other piece of porcelain with the tongs. Change the flame to blue and heat for 1 minute. Describe what happens to this piece of porcelain and draw it.



Figure 5 Which of these pieces of porcelain was heated in the yellow flame of a Bunsen burner?

Questions

1 Why do you think the yellow flame is called the safety flame?
2 Which flame is the noisiest: blue or yellow? Why is this helpful to know?
3 Which flame leaves a sooty carbon black deposit on whatever object it heats?
4 Which flame is the 'clean' flame for heating?
5 Give as many reasons as you can for using a blue flame for heating in an experiment.
6 When is the best time to use a safety flame?

1.5 Measuring mass and volume

SKILLS LAB

Aim

To measure mass and volume.

Risk assessment
1.5 Measuring mass and volume

Lab tech notes
1.5 Measuring mass and volume

What you need

- A variety of soft drinks
- Flavoured milk
- Fruit juices
- Bottled water
- Scales
- Measuring cylinder
- Beakers

What to do

1 On the sides of each container you will find a nutrition panel showing the volume of one standard serve and the amount of sugar in each drink. An example is shown in Figure 1.
Using the scales, measure out the mass of sugar in each serve of drink in a beaker.
2 In another beaker, carefully measure out the volume of a single serve of each drink.
3 Create a table to record the name of each drink, the sugar content per serve for each drink, how many serves of drink were in each container, and how much sugar there was in a whole container.



Figure 1 A nutritional panel

Questions

1 Which drink had the most sugar?
2 Which drink had the most serves in a single container?
3 Which drink had the most sugar in a whole container?
4 Was there any volume or sugar content that surprised you?

1.7 Heating water

SKILLS LAB

Aim

To heat water using a Bunsen burner.

Risk assessment
1.7 Heating water

Lab tech notes
1.7 Heating water

What you need

- Beaker
- Water
- Thermometer
- Retort stand
- Boss head
- Clamp
- Tripod
- Gauze mat
- Heat proof mat
- Stopwatch

What to do

1 Set up the equipment as shown in Figure 1.

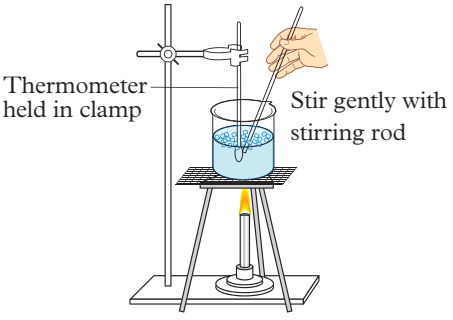


Figure 1 Equipment set up

2 Draw a scientific diagram of the equipment in your notebook.
3 Create a table with two columns, one for time (in minutes) and the other for temperature (in degrees Celsius), as per the example below.

Time (min)	Temperature (°C)

4 Measure the starting temperature of the water. Write this in the table as '0 min'.
5 Safely light the Bunsen burner and then open the collar to get a blue flame.
6 Heat the water over the Bunsen burner, recording the temperature of the water every minute for a total of 12 minutes.

Inquiry: What if another substance is added to the water?

1 Choose one of the inquiry questions below.
   - What if sugar was added to the water?
   - What if salt was added to the water?

2 Answer the following questions with regard to your inquiry question.
   - What is the hypothesis for your inquiry?
   - What *independent* variable will you change from the first method?
   - What *dependent* variable will you measure and/or observe?
   - What variables will you need to control to ensure a fair test? How will you control them?
   - Test your hypothesis.
   - Draw an appropriate graph for your data.

Questions

1 What type of data have you collected?
2 What type of graph should you draw for this type of data?
3 Does your graph support your hypothesis? Explain.
4 Was your experiment a fair test? Explain why or why not.

2.1 Measuring forces

SKILLS LAB

Aim

To measure a variety of forces in common situations.

Risk assessment
2.1 Measuring forces

Lab tech notes
2.1 Measuring forces

What you need

- Rubber band
- Thin strip of timber (or a ruler)
- Mass carrier and masses
- Pen

What to do

A rubber band can measure the size of forces in a similar way to a spring balance. But before it can, the rubber band must be calibrated. This means matching the stretch of the rubber band to the number of newtons pulling on it.

1 Calibrate the rubber band on the strip of timber, as shown in Figure 1.

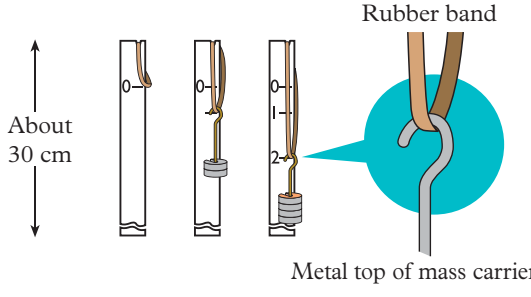


Figure 1 Calibrating the force measurer

2 Mark the distance that the rubber band is stretched on the timber when the mass carrier holds a 100 gram mass. Remember: The weight force of 100 grams equals 1 newton of force.

3 Repeat for masses of 200 grams, 300 grams, 400 grams and so on, marking the timber each time.

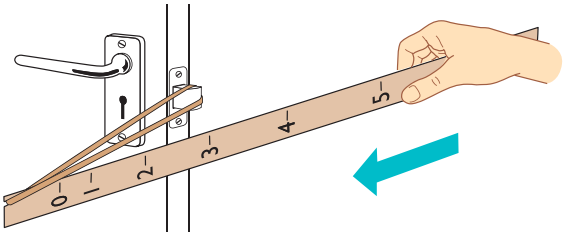


Figure 2 Measuring the force needed to open a door

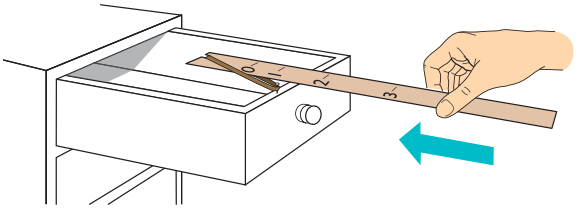


Figure 3 Measuring the force needed to close a drawer

4 Use your measuring device to measure the force needed to:
   a open the door to a room
   b drag a chair across the floor
   c close a drawer in the laboratory
   d move your pencil case
   e pull up your sock
   f carry out three movements of your choice.

Results

Draw a column graph showing the amount of force needed to move each object.

Conclusion

What do you know about the force required to move different objects?

2.2 Design a ball whacker

CHALLENGE

Design brief

Design equipment that uses a block of wood to hit a tennis ball. A block of wood from home or the woodwork room is ideal.

Risk assessment
2.2 Design a ball whacker

Lab tech notes
2.2 Design a ball whacker

Questioning and predicting

- How will you create a contact force between the wooden block and the ball?
- How will you make the wooden block swing?
- How far do you want your ball to move?

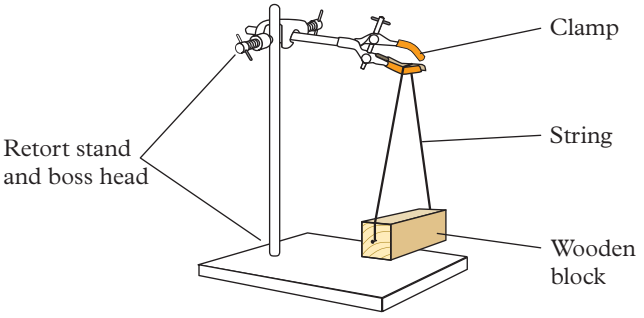


Figure 1 A possible design for the experiment

Planning and conducting

Figure 1 shows one way to set this experiment up. You must use only the force of gravity – you cannot push the wooden block.

Processing, analysing and evaluating

1. What changes did you have to make to move the ball further?
2. What was the most successful feature of your ball whacker? What was the least successful?
3. Is a heavy block better than a light one?
4. Is there any practical use for a 'whacker' like this?
5. If you were doing this experiment again, how would you modify your device? Explain.

Communicating

Present the various stages of your investigation in a formal experimental report.

2.4 What if the amount of friction was changed?

INVESTIGATION

Aim

To investigate how friction may be reduced.

Investigation
2.4 What if the amount of friction was changed?

Risk assessment
2.4 What if the amount of friction was changed?

Lab tech notes
2.4 What if the amount of friction was changed?

What you need

- Force measurer (see Skill Lab 2.1) or spring balance
- Thick textbook
- Wooden rollers (round pencils)
- Book
- Sand

What to do

1. Use your force measurer to measure the friction of your textbook being dragged along the table. (Hint: Drag it at constant speed.)
2. Place two books on top of each other and measure the friction.

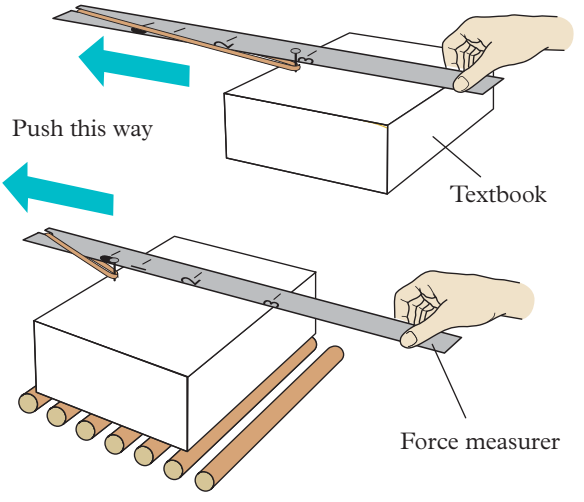


Figure 1 Measuring the friction of a textbook

Inquiry: Choose one question to investigate

1 What if rollers were placed under the textbook?
2 What if sand was placed under the textbook?
   - Write a hypothesis for your inquiry.
   - What (independent) variable will you change from the first method?
   - What (dependent) variable will you measure/observe?
   - What variables will you need to control to ensure a fair test? How will you control them?

Results

1 Record your results in a table like the one below.

Object	Force needed to make it move (N)			
	Trial 1	Trial 2	Trial 3	Average
Textbook				
Textbook with a second book on it				
Textbook with rollers under it				
Textbook with sand under it				

2 Draw a column graph showing the effect of sand/rollers on the object's friction.

Discussion

Compare your results with those of others in the class.

1 What was the best way to reduce friction?
2 Would 5 rollers be better than 2 for reducing friction?
3 Would 10 rollers be better than 5 for reducing friction?
4 Would bigger or smaller rollers be better for reducing friction?
5 What are some problems with using rollers?
6 Write down a practical example of rollers being used to reduce friction.
7 Why would square rollers not be any good?
8 Would fine sand or coarse (large-grained) sand be better for increasing friction?
9 Write down a practical example of sand being used to increase friction.
10 What are some problems with using sand for this purpose?

Conclusion

What do you know about how to reduce friction?

3.1 Can you use the push and pull of a magnet?

CHALLENGE

Design brief

Choose one of the following design briefs.

1 Have a magnet race. Who can push a magnet across the length of a desk the fastest?
2 Can you use the push force between two magnets to suspend the end of one magnet above the end of the other?



Risk assessment
3.1 Can you use the push and pull of a magnet?



Lab tech notes
3.1 Can you use the push and pull of a magnet?

3 Design an experiment to determine how far away your magnet needs to be to attract a metal paperclip. What if you used another magnet? Design an experiment to test if the second magnet has a stronger pulling force than the first magnet. Remember to control all other variables.

Questioning and predicting

1 Should you use like or unlike poles?
2 Do all magnets have equal force?
3 Which part of a magnet has the strongest force?

Processing and analysing

1 What changes did you have to make to improve your design?
2 What was the most successful feature of your design? What was the least successful?
3 Is there any practical use for your design?
4 If you were doing this experiment again, how would you modify your design? Explain.

Communicating

Present the various stages of your investigation in a formal experimental report.

3.3 What if a balloon was electrostatically charged?

INVESTIGATION

Aim

To examine the push or pull forces involved in electrostatically charged balloons.

Risk assessment
3.3 What if a balloon was electrostatically charged?

Lab tech notes
3.3 What if a balloon was electrostatically charged?

What you need

- Two balloons
- String
- Wool/nylon material

Caution

Some students may be allergic to latex balloons.

What to do

1. Blow up both balloons and tie knots in the ends.
2. Tie string to the ends of both balloons.
3. Rub one of the balloons on your jumper or with the material provided.
4. Hold the balloon by the string so that it does not lose its charge.
5. Hold the second balloon by the string and bring it close to the first balloon.
6. Would you describe the force as a push or pull force?
7. Does the balloon have to make contact for the force to be noticed?

Inquiry: What if both balloons are charged?

1. Which (independent) variable will you change from the first method?
2. Which (dependent) variable will you measure/observe?
3. Name three variables you will keep the same/control.
4. Write a hypothesis for your inquiry.
5. Describe what happened.
6. Explain why it happened.

Discussion

1. Are electrostatic forces contact or non-contact forces?
2. Did a single charged balloon exert a push or a pull force on the non-charged balloon?
3. Did the two charged balloons exert a push or pull force on each other?

Conclusion

What do you know about electrostatic forces?

3.4 Calculate weights in the solar system

SKILLS LAB

Aim

To heat water using a Bunsen burner.

Risk assessment
3.4 Calculate weights in the solar system

Lab tech notes
3.4 Calculate weights in the solar system

The effects of gravity are affected by the mass of the objects involved. Gravity on the Earth is determined by the mass of Earth. How this gravity affects objects on the Earth is determined by their mass.

By doing some simple calculations, you can work out your weight if you lived on the Sun, other planets in the solar system or the Moon. Note that the Earth has a gravity factor of 1, which is often referred to as 1*g*. To calculate weight, you will need to multiply mass (the reading on the bathroom scales) by the gravity factor for the planet, Sun or Moon. Remember that weight is measured in newtons.

1. Using the Earth's gravity factor, calculate the weight of a 65 kilogram person on the Earth and record it in Table 1 (in the first row).
2. Complete Table 1, filling in the weight for the 65 kilogram person on the other planets, the Sun and the Moon.
3. Imagine holding an Olympic Games on the different astronomical bodies listed in Table 1. Based on your calculations, do you think the gravity factor for the planet would affect the results of the events? For example, would diving or high jump be affected? What about other events?
4. How would gravity affect your lifestyle on Mercury compared with Jupiter? What everyday tasks would be easier or harder to complete? Explain.

Table 1 A person's weight in the solar system

Celestial body	Gravity factor	Person's mass (kg)	Person's weight (N)
Earth	1.00	65.00	
Mercury	0.38	65.00	
Venus	0.90	65.00	
Mars	0.38	65.00	
Jupiter	2.87	65.00	
Saturn	1.07	65.00	
Uranus	0.93	65.00	
Neptune	1.23	65.00	
Sun	27.80	65.00	
Moon	0.16	65.00	

4.2 What if the amount of elastic potential energy was increased?

INVESTIGATION

Aim

To investigate how elastic potential energy can be used to power a boat.

Risk assessment
4.2 What if the amount of elastic potential energy was increased?

Lab tech notes
4.2 What if the amount of elastic potential energy was increased?

CAUTION! Consider pool safety. Students must be supervised at all times.

What you need

- Waxed cardboard (milk cartons work well)
- Scissors
- Rubber band
- Butterfly pins
- Water bath or swimming pool

What to do

1 Cut out the waxed cardboard to match the diagram in Figure 1.

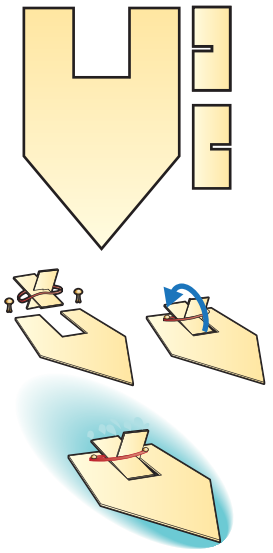


Figure 1 The parts and method of assembly for a rubber band boat

2 Put the rubber band around the propeller and attach it to the boat using butterfly pins.
3 Wind the propeller anticlockwise, place the boat in the water and release it.
4 Measure how far the boat travels.

Inquiry: What if more elastic potential energy was stored in the rubber band propeller?

1 Write a hypothesis for your inquiry.
2 Which (independent) variable will you change from the first method?
3 Which (dependent) variable will you measure/observe?
4 Which variables will you need to control to ensure a fair test? How will you control them?

Results

1 Complete the following table.

Number of rotations of the propeller	Distance the boat travelled (attempt 1)	Distance the boat travelled (attempt 2)	Distance the boat travelled (attempt 3)	Average distance the boat travelled
1				
2				
3				
4				
5				

2 Draw a line graph showing the effect of increasing the elastic potential energy of the propeller on the distance the boat travelled.

Discussion

1 Did you collect qualitative or quantitative data for this experiment? Explain.
2 Why did you make three attempts at each propeller rotation to determine the average distance travelled?
3 What type of energy did the elastic potential energy get converted to?
4 Your hands provided the energy to wind the propeller. Where did this energy come from?

Conclusion

Describe the relationship between the potential energy given to the propeller and the distance the boat moved.



Figure 2 Milk cartons are required for this experiment.

4.3 Drawing flow diagrams of energy transfer

SKILLS LAB

Aim

To draw energy flow diagrams.

Risk assessment
4.3 Drawing flow diagrams of energy transfer

Lab tech notes
4.3 Drawing flow diagrams of energy transfer

CAUTION! Boiling water and steam can cause severe burns. Keep face and hands clear.

What you need

- Station 1: Battery, wires, small buzzer
- Station 2: Tuning fork
- Station 3: Plastic cup, water, salt, aluminium strip, copper strip, 2 wires, multimeter
- Station 4: Plastic windmill, kettle
- Station 5: Toy car, ramp, measuring tape

What to do

1. Spread around the room are stations with different types of energy.
2. Complete Table 1, identifying the object where you first see evidence of the energy and the object where you last see the energy.

Table 1 What to do at each station

Station	What to do	Where does the energy come from?	Which object or part of the object has the energy last?
1	> Connect the battery to a buzzer.		
2	> Gently tap the forked end of the tuning fork on the table. > What do you notice happens?		
3	> Fill most of the cup with water. > Add 1 tablespoon of salt to the water. > Fold a strip of aluminium and a strip of copper over opposite sides of the cup so that one end is in the salt water and the other end is on the outside of the cup. > Attach wires to the outside edges of the metal strips. > Connect the multimeter to the wires and check the voltage reading. > What energy does the multimeter read at this station? > Where did this energy come from?		
4	> Blow on the plastic windmill. > What energy makes the windmill move? > Where did this energy come from? > Hold the plastic windmill over a boiling kettle, being careful not to burn yourself with the steam. > Where is the energy coming from this time?		
5	> Set up the ramp so that the top end is 10 cm above the ground. > Place the car at the top of the ramp. > Allow the car to roll down the ramp and along the floor. > How far did the car roll? > Where did the energy for the car to move come from? > How could you increase this energy?		

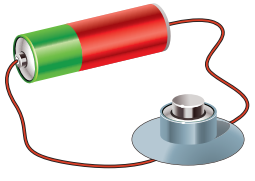


Figure 1 Use wires to connect the buzzer to the battery.



Figure 2 Where does the sound energy come from or transfer from?

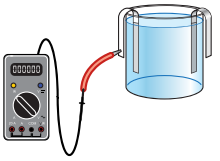


Figure 3 Connect the saltwater battery to a multimeter.



Figure 4 A toy windmill acts like an electricity generating turbine.

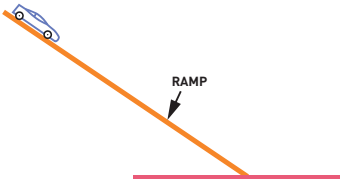


Figure 5 What path does the energy take as the car moves down the ramp?

4.4 Investigating heating by convection

INVESTIGATION

Aim

To investigate heating water by convection.

Risk assessment
4.4 Investigating heating by convection

Lab tech notes
4.4 Investigating heating by convection

CAUTION! Always wear safety glasses, lab coat and tie long hair back, when using a Bunsen burner. Allow all hot equipment to cool before handling.

What you need

- Water
- Food colouring
- Bunsen burner
- Tripod
- Heatproof mat
- Pyrex 600 mL beaker
- Dropper or pipette

What to do

1 Set up the equipment as shown in Figure 1.

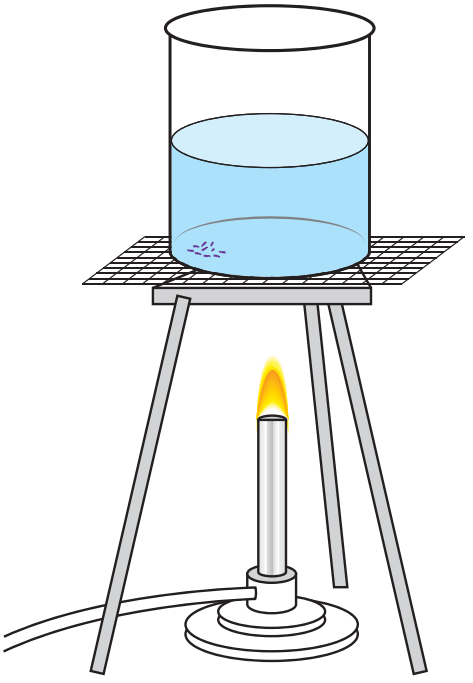


Figure 1 Experimental set-up

2 Fill the beaker with water. Add a drop of food colouring to the bottom of the full beaker using a dropper or pipette.

3 Heat the water gently over the Bunsen burner and observe the movement of the food colouring. (If possible, use a small flame and no heatproof mat between the Bunsen burner and the beaker – you can do this with Pyrex beakers.)

4 Note the path that the food dye takes from the burner to the top of the water and back down again.

Results

Draw a labelled diagram showing the movement of the coloured water.

Discussion

1 Describe the movement of the coloured water.

2 Why do you think the coloured water moved like this?

3 What was happening to the particles in the water when the water was being heated?

Conclusion

What do you know about heating water by convection?

4.5 Protection from heat radiation

CHALLENGE

Design brief

Design protective equipment that will protect firefighters against the radiant heat of bushfires.

Risk assessment
4.5 Protection from heat radiation

Lab tech notes
4.5 Protection from heat radiation

Criteria limitations

Any material must be easily available and be able to be sewn or glued into the required shape. The commercial cost of the material must be within the limit set by your teacher.

Questioning and predicting

- What materials will you use to construct the protective equipment?
- How much material will you need to construct your garment?
- What colour should your garment be? (Does this make a difference?)
- What added features (such as pockets) will you need to add?

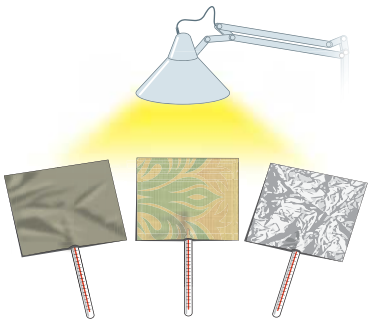


Figure 1 Experimental set-up – place the bulbs of thermometers under the different materials and then place them in the sun (or at 6 cm from a lamp).

Planning and conducting

- How will you measure the radiant heat that passes through the material?
- How long will you expose the material to the heat source? Figure 1 shows the general set-up of the experiment.

Processing and analysing

1. Use a graph to describe the rate of temperature increase under all the tested material.
2. Which material was the most successful at reflecting the radiated heat?
3. What were the limitations of this material? Availability? Cost? Useability?
4. Would it be possible to create a large-scale version of your design for a firefighter? What would be the cost of your design?
5. If you were doing this experiment again, how would you modify your design? Explain.

Communicating

Present the various stages of your investigation in a formal experimental report.



Figure 2 Firefighters require protective equipment against the radiant heat of bushfires.

4.6A Demonstrating electrostatics

CHALLENGE

Aim

To observe electrostatic charge in action.

Risk assessment
4.6A Demonstrating electrostatics

Lab tech notes
4.6A Demonstrating electrostatics

What you need

- Plastic comb
- Wool cloth
- Rice Bubbles®
- Large plastic bag with tie
- Plastic rod or pen
- Ebonite rod
- Small pieces of paper
- Balloons
- Felt-tipped pens
- String

What to do

Part A

1. Rub the plastic rod with the wool and then place it near the Rice Bubbles®. Record your observations.
2. Put some of the Rice Bubbles® in the plastic bag. Blow air into the bag and seal it with the tie. Record your observations.
3. Rub the wool over the plastic bag.
4. Rub the wool over the comb and the plastic bag. Move the wool over the plastic bag and record the movement of the Rice bubbles as a result.
5. Explain your observations using the idea of electrostatic charge.

Part B

1. Rub the plastic rod or pen and bring it close to some small pieces of paper.
2. On a piece of paper, draw four positive and four negative charges. Show what happens to these charges when the positively charged wool is brought close to them.
3. Explain why the paper is attracted to the plastic rod or pen by discussing the movement of charges.

Part C

1. Blow up a balloon and draw a face on it (take care as some felt-tipped pens may cause the balloon to pop).
2. Tie the balloon onto a string and suspend it from a doorway or ceiling using tape so that it is level with your head.
3. Rub the face with a wool cloth and walk towards it.
4. Record what happens.
   - How close do you have to be before your 'balloon face' is attracted to you?
   - What happens if you put a piece of paper between you and the balloon?
5. Blow up another balloon and draw a face on it. Tie it with a string and rub it with a woollen cloth.
   - What happens when you bring it close to your other balloon?
   - Explain your observations using the idea of electrostatic charge.

Part D

1. Set up a thin stream of water from a tap.
2. Rub a plastic rod with a piece of wool.
3. Place the charged rod near the stream of water without touching it.
4. Record what happens. Explain your observations using the idea of electrostatic charge.

4.6B Making a simple torch circuit

CHALLENGE

Aim

To construct a simple circuit.

Risk assessment
4.6B Making a simple torch circuit

Lab tech notes
4.6B Making a simple torch circuit

What you need

- Pieces of insulated electrical wire with the ends stripped bare
- 1.5 V battery
- 1.2 V torch globe
- Hand lens

What to do

1. Try different arrangements of the wires, battery and torch globe to make the globe light up.
   - How many of your arrangements work?
   - How many of your arrangements do not work?
2. Use circuit diagrams to record some of the arrangements that work and some that do not.
   - Can you explain why some arrangements work and others do not?
3. Use the hand lens to look carefully at the filament in the globe. The filament is the tiny wire inside the glass of the globe – the part that glows brightly when the globe lights up. Draw what you see.
   - How does this explain why the wires have to be connected in a particular way for the globe to light?
4. Look at how a globe holder (the base of a globe) is constructed.
   - Can you see how the connections are made inside the holder?

5.1 What if you bounced a ball?

INVESTIGATION

Aim

To investigate the energy efficiency of a bouncing ball.

Risk assessment
5.1 What if you bounced a ball?

Lab tech notes
5.1 What if you bounced a ball?

What you need

- Tennis ball
- Metre ruler
- A selection of other types of balls

What to do

1. Hold the tennis ball 1 m above the ground next to the vertical ruler.
2. Drop the ball (do not throw it) on a hard surface.
3. Use the metre ruler to measure how high the ball bounces back. Be careful to avoid parallax error by ensuring your eye is parallel with the ball.
4. Determine the percentage energy efficiency by using the formula below:

$$\text{Percentage efficiency} = \frac{\text{height of bounce}}{\text{starting height}} \times \frac{100}{1}$$

Inquiry: Choose one of the following questions to investigate

- What if another ball was bounced on the same surface? (Does it have the same efficiency?)
- What if the same ball was bounced on another surface? (Does it have the same efficiency?)

Answer the following questions in relation to your inquiry.

- Write a hypothesis for your inquiry.
- Which (independent) variable will you change from the first method?
- Which (dependent) variable will you measure/observe?
- Write a list of variables you will need to control to ensure a fair test. Describe how you will control each variable.

Results

1 Complete the following table.

Dependent variable (surface/ball)	Attempt 1	Attempt 2	Attempt 3	Average

2 Draw a column graph showing the results of your experiment.

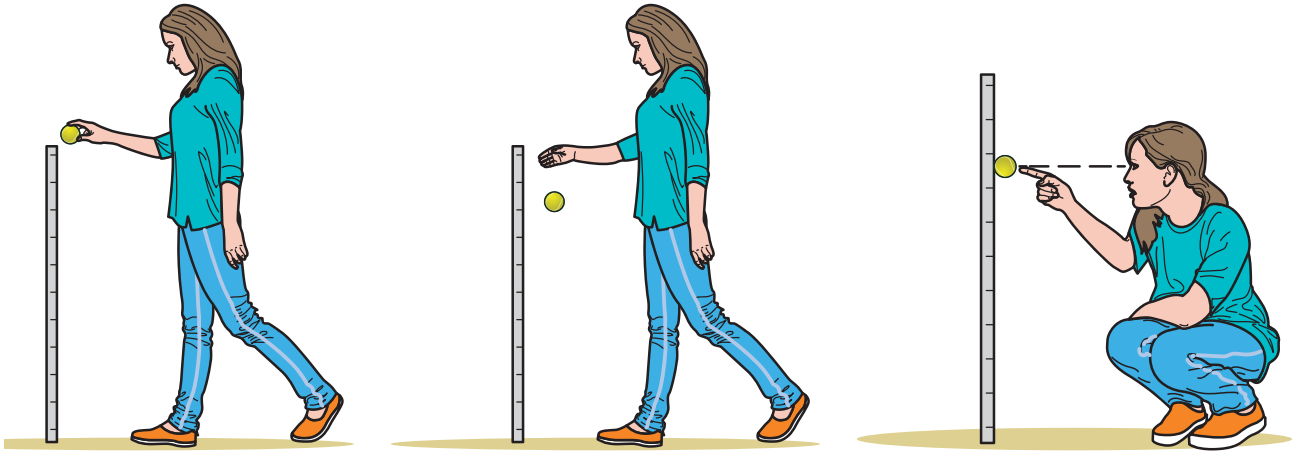
Discussion

1. Describe the results of your experiment.
2. Did your experiment support your hypothesis?
3. What type of energy did the ball have:
   - before it was dropped
   - just before it hit the ground
   - as it touched the ground?
4. Where did the waste energy go?
5. Draw a flow diagram of the energy transformation.
6. Draw a flow diagram of the energy transfer.

Conclusion

Describe the evidence that supported or refuted your hypothesis.

Figure 1 Experimental set-up



5.2 Designing an energy-efficient house

CHALLENGE

Design brief

Risk assessment
5.2 Designing an energy-efficient house

Lab tech notes
5.2 Designing an energy-efficient house

Design and build two identical houses out of cardboard or wood. Add a feature to one of the houses that will make it more efficient in staying cool. Test your design feature by exposing both houses to an energy source (a strong light) and determine the rate of temperature increase for each house.

Criteria restrictions

- Only one feature may be added to the second house.
- The feature must represent a design feature that is currently available to homeowners.
- The feature must be proportionate in size to the house.

Questioning and predicting

- Which feature will you add?
- What materials will you use?
- Why do you think your added feature will keep the house cool?

Planning and conducting

- How will you measure the temperature of the two houses?
- How long will you expose the houses to the energy source?

Processing and analysing

1. Describe the rate of temperature increase in both houses.
2. How successful was your feature?

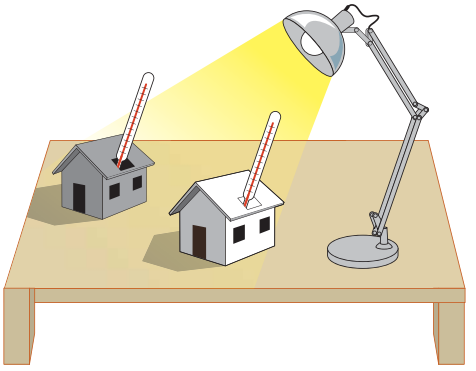


Figure 1
General set-up of experiment

3. What were the limitations of your design?
4. Would it be possible to create a large-scale version of your design for a real house?
5. If you were doing this experiment again, how would you modify your device? Explain.

Communicating

Present the various stages of your investigation in a formal experimental report.

5.3 What time of day does the Sun produce the most energy?

INVESTIGATION

Aim

Risk assessment
5.3 Investigating energy transformations

Lab tech notes
5.3 Investigating energy transformations

To investigate the effect of weather conditions on the amount of energy produced by a solar panel.

What you need

- Solar panel
- Motor with propeller
- Wires
- Sunshine
- Timer

What to do

1. Connect the solar panel to the motor using the wires.
2. Record the weather conditions.
3. Expose the solar panel to sunshine. Count how many times the propeller rotates in 1 minute.
4. Repeat this test at different times of the day, or on different days.
5. Record your data in the following table.

Date	Time	Revolutions of propeller/minute	Weather conditions

Discussion

1. What time of day does the Sun produce the most light energy?
2. Why should you take readings over several days?
3. Why did you record the weather conditions?
4. Draw a flow diagram that shows the energy transformations for your challenge.

6.1 Identifying rocks

CHALLENGE

Aim

To identify rocks using observable properties.

Risk assessment
6.1 Identifying rocks

Lab tech notes
6.1 Identifying rocks

What you need

- Rock samples (unnamed, perhaps labelled 'A', 'B', 'C', 'D' etc.)
- Hand lens
- Table 1

Table 1 Key for common types of rocks

1	Does the rock have layers? (Use a magnifying glass to check.)	Yes – Go to 3 No – Go to 2
2	Can you see cracks in the rock?	Yes – Go to 4 No – Go to 5
3	Can sand be rubbed off the rock?	Yes – Sandstone No – Go to 8
4	Is the rock a light colour (i.e. mostly white)?	Yes – Marble No – Go to 10
5	Does the rock look like glass?	Yes – Obsidian No – Go to 6
6	Does the rock have a lot of holes that make it light to hold?	Yes – Pumice No – Go to 7
7	Is the rock grey to black?	Yes – Basalt No – Limestone
8	Can you see crystals in the rock?	Yes – Gneiss No – Go to 9
9	Can you easily split the rock into thin, flat pieces?	Yes – Slate No – Shale
10	Does the rock have a lot of holes that make it light to hold?	Yes – Pumice No – Granite

What to do

1. Examine each rock sample with the hand lens and use the key in Table 1 to identify it. Be aware of the following:
   - Crystals in rocks have straight edges and flat, shiny surfaces.
   - Grains are not shiny, are jagged or rounded and are more like grains of sand.
   - Coarse grains are about the size of a grain of rice, medium grains are smaller but still visible to the naked eye, and small grains are only visible with a hand lens or magnifier.
2. Display your results in a table that identifies the rock sample (e.g. sample A), lists its main properties and gives its name.

Discussion

1. How difficult was it to identify your rock samples?
2. Were there any samples you could not identify?
3. Compare your results with those of another group. Were there any differences between your results?
4. Ask your teacher for the names of your rock samples and see which ones you got right (hopefully all of them).

Conclusion

What do you know about identifying rocks?



Figure 1 This experiment requires rock samples.

6.3 What affects crystal size?

INVESTIGATION

Aim

To grow crystals and determine what affects their size.

Risk assessment
6.3 What affects crystal size?

Lab tech notes
6.3 What affects crystal size?

CAUTION! Wear safety glasses, lab coat and tie long hair back, when using a Bunsen burner. Allow all hot equipment to cool before handling.

What you need

- Alum solution
- Bunsen burner
- Matches
- Heatproof mat
- Tripod
- Gauze mat
- 2 Petri dishes
- Evaporating dish
- Safety glasses
- 250 mL beaker
- Tablespoon

What to do

1 Prepare a solution of alum by mixing two and a half tablespoons of alum with half a cup of hot water. Stir until the alum is dissolved.
2 Pour roughly equal amounts of alum solution into the evaporating dish and the two Petri dishes.
3 Put one of the Petri dishes in the refrigerator.
4 Put the other Petri dish on a windowsill.
5 Place the evaporating dish on the gauze mat.
6 While wearing safety glasses, gently heat the evaporating dish containing the alum solution over a yellow (safety) flame. The yellow flame is cooler and will allow for gentle boiling.
7 Stand back from the evaporating dish and Alum solution while heating as the solution may spit and splatter. Continue heating the solution until nearly all the water has evaporated.
8 Observe the size of the crystals formed in the evaporating dish.
9 After 2 days, observe the size of the crystals formed in the two Petri dishes.
10 Observe the crystals formed in the refrigerator again after 4 or 5 days.

Results

Draw a labelled diagram of the crystals formed in the evaporating dish and in the two Petri dishes. Your diagram needs to show the different sizes of the crystals in the different dishes.

Discussion

1 What was the independent variable for this experiment?
2 What was the dependent variable?
3 Name three variables you needed to control.
4 Each of these crystals grew over a different time span. How does the time allowed for the crystal to form affect the size of the crystals?

Conclusion

What do you know about the factors affecting crystal size?



Figure 1 This experiment requires explores crystals.

6.5 Making a metamorphic rock

SKILLS LAB

Aim

To make a sample of a metamorphic rock.

Risk assessment
6.5 Making a metamorphic rock

Lab tech notes
6.5 Making a metamorphic rock

What you need

- 2 shale rock samples from Skills lab 6.6
- Bunsen burner
- Tripod
- Pipe clay triangle
- Gauze mat
- Evaporating dish
- Tongs
- 2 × 250 mL beakers

What to do

1. Allow your shale samples to dry for approximately 1 week.
2. Place one of the shale samples on a pipe clay triangle on top of a gauze mat. Heat strongly over a blue Bunsen burner flame for about half an hour. You could place an evaporating dish upside down over the shale to retain more heat.
3. After about half an hour of heating, allow the sample to cool for 10 minutes. Then use the tongs to carefully pick up the shale sample and drop it into a beaker of water.
4. Drop the second unheated shale sample into another beaker of water and observe what happens to the two rock samples.

Results

Record your observations in a table.

Discussion

1. What differences do you notice about the two rock samples when they are dropped into the water?
2. Can strong heat change the properties of rocks over time?
3. How different was your new metamorphic rock sample from the original shale sample? Was the method successful?

Conclusion

What do you know about the formation of metamorphic rocks?

6.6 Making sedimentary rocks

SKILLS LAB

Aim

To make small samples of sedimentary rocks and compare them against real samples.

Risk assessment
6.6 Making sedimentary rocks

Lab tech notes
6.6 Making sedimentary rocks

What you need

- Dry clay
- Dry sand
- Plaster of Paris
- Small, smooth pebbles
- Samples of sedimentary rocks
- Water
- Mortar and pestle
- Teaspoon
- 4 empty matchboxes
- White tile

What to do

1. Grind a lump of dry clay with the mortar and pestle until the clay is fine and powdery.
2. Using the teaspoon, mix the dry ingredients for each rock sample on a white tile according to the recipes below, but don't add the water just yet. You will need to prepare two shale samples to use in Skills lab 6.5.

Rock	Number of teaspoons of				
	dry clay	sand	plaster of Paris	pebbles	water
Sandstone	0.5	4	0.5	0	2
Shale	5	0.5	0	0	2
Conglomerate	0.5	1	0.5	4	2

3. Pile up your ingredients into a little hill and make a small dip in the centre for the water.
4. Slowly add the water and stir until the ingredients are uniformly mixed. Be careful not to make the mixture too wet.
5. Press your mixture into an empty matchbox, label it with the rock type and your name, and leave it to dry for 2 days.
6. When your 'rock' is dry, peel off the matchbox and examine your sample. Take digital photos of your samples and photos of the 'real' rocks for comparison. Keep your two shale samples for Skills lab 6.5.

Results

Include images of your rocks here, along with any statements about the process or products.

Discussion

1. In what ways were your rocks similar to real sedimentary rocks?
2. What were the differences between your samples and the real rocks?

Conclusion

What have you discovered about sedimentary rocks?

6.8 Modelling the rock cycle

CHALLENGE

Aim

To model the rock cycle.

Risk assessment
6.8 Modelling the rock cycle

Lab tech notes
6.8 Modelling the rock cycle

CAUTION! Wear safety glasses, lab coat and tie long hair back, when using a Bunsen burner.

What you need

- Crayons
- Sharpener
- 2 sheets of aluminium foil
- 2 wooden blocks
- Beaker
- Bunsen burner
- Large clamp
- Tripod
- Gauze mat
- Stirring rod
- Matches

What to do

1. Remove the paper from the crayons.
2. Shave the crayons into small piles. Keep each colour in a separate pile.
3. Cover one wooden block with aluminium foil.
4. Sprinkle a layer of crayon shavings over the aluminium foil to form the first layer.
5. Repeat step 4 for the remaining colours of crayons.
6. Cover the layers of crayons with another sheet of aluminium foil.
7. Place the second wooden block on top of the foil and press down with as much pressure as possible.
8. Remove the top block and aluminium foil and examine the compacted shavings.
9. Place the shavings between the aluminium foil and wooden blocks again.
10. Apply the large clamp around the wooden blocks and shavings. Tighten the clamp as much as possible.
11. Remove the clamp and examine the compacted crayon shavings.
12. Place the compacted crayon shavings into the beaker.
13. Heat the compacted crayon shavings over the Bunsen burner, stirring occasionally until melted.

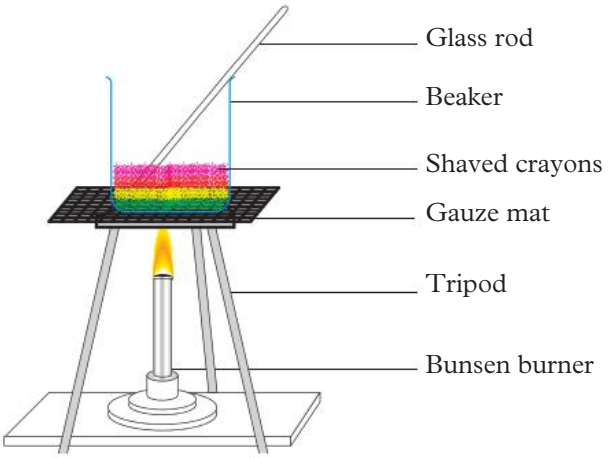


Figure 1 Experimental set-up

14. Allow the crayon mixture to cool.
15. Examine the resulting crayon sample.

Questions

1. Which type of weathering – mechanical or chemical – took place at step 2?
2. What term is used to describe the movement of the sediment pile of crayon shavings onto the aluminium foil at step 4?
3. What type of rock did you form in step 8?
4. What type of rock did you form in step 11?
5. What type of rock did you form in step 15?
6. What are the similarities and difference between the three forms of rock you formed?



Figure 2 Crayons are required for this experiment.

7.2 Modelling the phases of the Moon

CHALLENGE

Aim

To model the phases of the Moon.

Risk assessment
7.2 Modelling the phases of the Moon

Lab tech notes
7.2 Modelling the phases of the Moon

What you need

- Torch or lamp with exposed light bulb
- Globe or basketball
- Tennis ball
- 8 small foam balls or ping pong balls

What to do

1. In small groups, use a torch or light bulb in a fixed position to represent the Sun. One person should then hold a globe or basketball to represent the Earth, and another should hold a tennis ball to represent the Moon.
2. Begin by rotating the Earth as it orbits the Sun. Try to work out how the Moon would orbit the Earth as the Earth orbits the Sun.
   - Does this explain why we only see one side of the Moon?
   - When people refer to the 'dark side of the Moon', are they always talking about exactly the same side?
3. Draw the Earth and Sun on a piece of paper. Colour half the foam balls. Rotate the balls so that varying amounts of light and shadow are shown so that all phases of the Moon are represented.
4. Observe the Moon as the Earth comes between it and the Sun to create a lunar eclipse.
   - During which phase of the Moon does a lunar eclipse occur?



Figure 1 This experiment will further your understanding of the phases of the Moon.

7.3 Modelling the seasons

CHALLENGE

Aim

To model the seasons.

Risk assessment
7.3 Modelling the seasons

Lab tech notes
7.3 Modelling the seasons

What you need

- Torch or lamp with exposed light bulb
- Globe or basketball

What to do

1. Use a torch or light bulb in a fixed position to represent the Sun. One person should then hold the globe or basketball to represent the Earth.
2. The Earth is tilted as it orbits the Sun. Hold your model Earth so that it is tilted slightly. Imagine that the axis is tilted to point towards the numbers 1 and 7 on a clock face. Do not change this tilt during the activity.
3. Walk slowly in a circle around the lamp, at the same time rotating the model Earth. Make sure the tilt always points in the same direction. When it is summer in Australia, the Sun is almost overhead. In winter, the sunlight arrives at an angle and is more spread out.
   - When you have walked half a circle around your Sun, stop and look at the model Earth. How is it different? Which part of the Earth is having summer?

8.2 Can you increase the output of a power station?

CHALLENGE

Design brief

Modify the design of a model power station so that you increase the rate at which the turbine spins.

Risk assessment
8.2 Can you increase the output of a power station?

Lab tech notes
8.2 Can you increase the output of a power station?

CAUTION! The boiling water in the beaker will have made the sides of the beaker hot. Be careful when placing the foil to avoid burns.

Criteria restrictions

Only the following materials can be used:

- Square paper (15 cm × 15 cm) cut from one A4 sheet
- Ruler
- Pencil with eraser on the end
- Scissors
- Pin
- Electric kettle
- Bunsen burner
- Tripod
- Gauze mat
- 250 mL conical flask
- Aluminium foil (1 piece, 10 cm × 10 cm)
- Large nail

Questioning and predicting

- How could you improve the turbine?
- How could you increase the production of steam?
- How could you ensure the quantity and speed of the steam that hits the turbine?

Planning and conducting

THE TURBINE

1 Mark the square paper as shown in Figure 1 using a pencil and a ruler. Draw a circle in the centre about the size of a 5 cent piece.

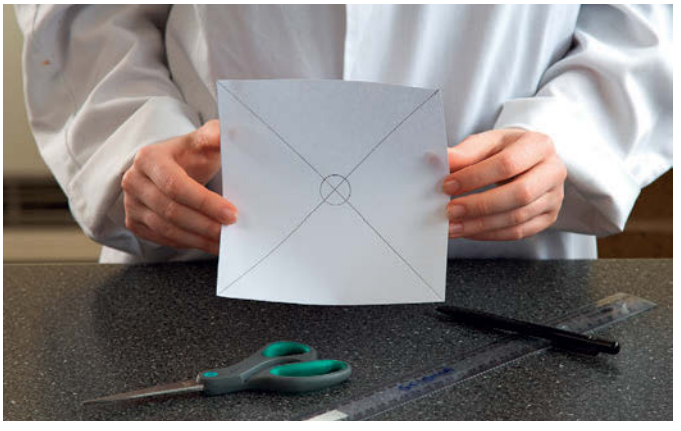


Figure 1 Marking the square paper using a pencil and ruler

2 Cut along the lines but stop at the edges of the circle.
3 Fold all four corners in towards the centre, one at a time, and hold them in place.
4 Insert a pin through the four corners and into the tip of the pencil's eraser.
5 Blow on the pinwheel to see if it spins (see Figure 2). If not, pull the pin out slightly to create room for the paper to spin. The pinwheel will act like the turbine of the power station.



Figure 2 Blowing on the pinwheel

THE BOILER

1 Set up your Bunsen burner, tripod and gauze mat. Place the beaker on top of the gauze mat. Do not light the bunsen burner.
2 Boil the kettle and transfer the boiling water to the flask.
3 Use the nail to punch a small hole in the centre of the aluminium foil.
4 Place the aluminium foil over the top of the flask and fold it down the sides of the flask.
5 Light your Bunsen burner and heat the water until it boils again.
6 Steam should be coming out of the hole. Hold your pinwheel over the hole and let the steam spin the 'turbine'.

Processing and analysing

1 Describe what happened to your pinwheel when it was placed in the steam flow.
2 What else would you need to add to make your 'power station' generate electricity?
3 What is the fuel in your power station?
4 Will your power station run out of fuel?

Communicating

What do you know about the action of a power station?

8.3 Can you increase the power of solar cells?

CHALLENGE

Design brief

Modify the design of a solar cell so that it produces the highest voltage.

Risk assessment
8.3 Can you increase the power of solar cells?

Lab tech notes
8.3 Can you increase the power of solar cells?

What you need

- Small solar cells
- Electrical wires
- Voltmeter

Questioning and predicting

- How could you maximise the amount of sunlight that the solar cell receives?
- Does cleaning the solar cell improve the voltage produced?
- How could you connect more than one solar cell so that the amount of voltage produced increases?

Planning and conducting

1 While inside, connect a solar cell to the voltmeter using the electrical wires.
2 While still inside, record the voltmeter reading.
3 Cover the solar cell with your hand and record the voltmeter reading.
4 Take the solar cell over to a window and record the voltmeter reading.
5 Take the solar cell outside, face it towards the sun and record the voltmeter reading. If it is cloudy outside, take a reading and then repeat the measurement when the clouds clear or on another day when it is sunny.
6 Cover the solar cell with a thin layer of dust and repeat the measurement.
7 Connect solar cells together in series (that is, in a line) and record the voltmeter reading.

Processing and analysing

1 Record your results in a table like the one shown below.

Location	Number of solar cells	Voltmeter reading (V)
Inside		
Inside, covered		
Window		
Outside, sunny		
Outside, cloudy		
Outside, dusty		
Outside, multiple cells		

2 What are the best conditions for generating electricity from a solar cell?
3 Why do you think a house with a solar energy installation will have six, eight or more solar cells on its roof?
4 Why should solar panels on a house roof be cleaned regularly?

Communicating

What do you know about the amount of electricity produced by solar cells?

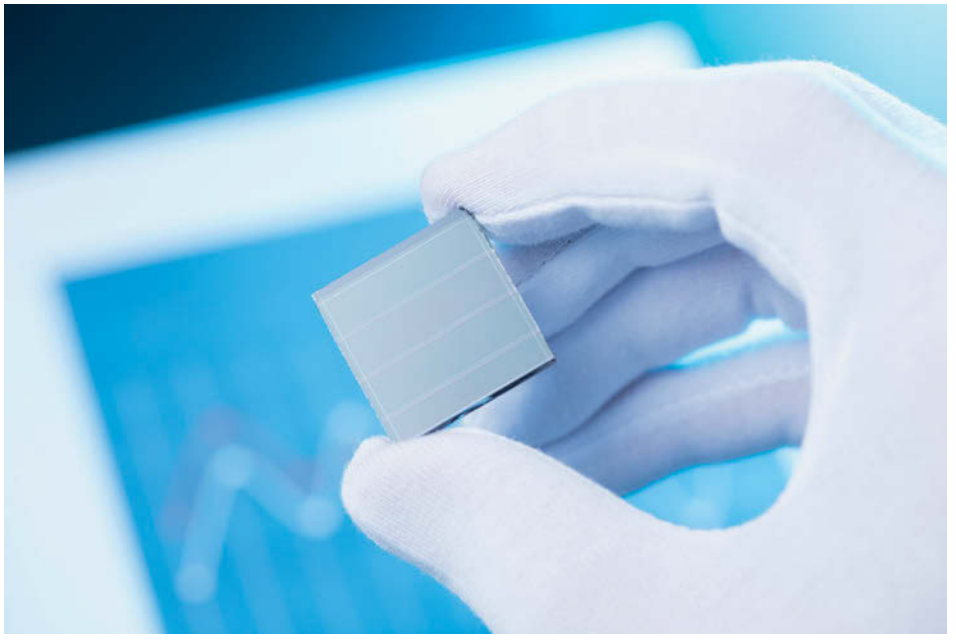


Figure 1 Small solar cells are required for this experiment.

8.4B What if a metal was obtained from a mineral?

INVESTIGATION

Aim

To obtain pure copper from the mineral copper sulfate.

Risk assessment
8.4B What if a metal was obtained from a mineral?

Lab tech notes
8.4B What if a metal was obtained from a mineral?

What you need

- Power supply
- 2 electrical leads with alligator clips on one end
- 2 carbon rods
- 250 mL beaker
- 0.5 M copper sulfate solution
- Safety glasses
- Paper towel

What to do

1. Plug the electrical leads into the DC terminals of the power supply.
2. Connect the top end of the carbon rods to the alligator clips on the end of the electrical leads.
3. Fill the beaker with approximately 100 mL of the copper sulfate solution.
4. Place the carbon rods into the copper sulfate solution, being careful not to let them touch each other or the beaker.
5. Set the power supply knob to 6 V and turn the power on.
6. Observe the rods over the next 10 minutes.
7. After 10 minutes, turn the power supply off. Remove the carbon rods and place them on paper towel.

Inquiry: Improving metal production

1. Choose one of the inquiry questions below.
   - What if the voltage was increased?
   - What if more copper sulfate was used?
2. Answer the following questions with regard to your inquiry question.
   - Write a hypothesis for your inquiry.
   - Which (independent) variable will you change from the first method?
   - Which (dependent) variable will you measure and/or observe?
   - Name three variables you will keep the same or control.
   - What variables will you need to control to ensure a fair test? How will you control them?

Results

Record your observations about the appearance of the rods and the copper sulfate solution.

Discussion

1. Examine something else made of copper, such as an old 1 or 2 cent coin or a copper water pipe. Does the coating on the rods look like pure copper?
2. Where did the copper coating come from?
3. What do you think the electricity did in this experiment?

Conclusion

How successful were you in obtaining pure copper from copper sulfate?

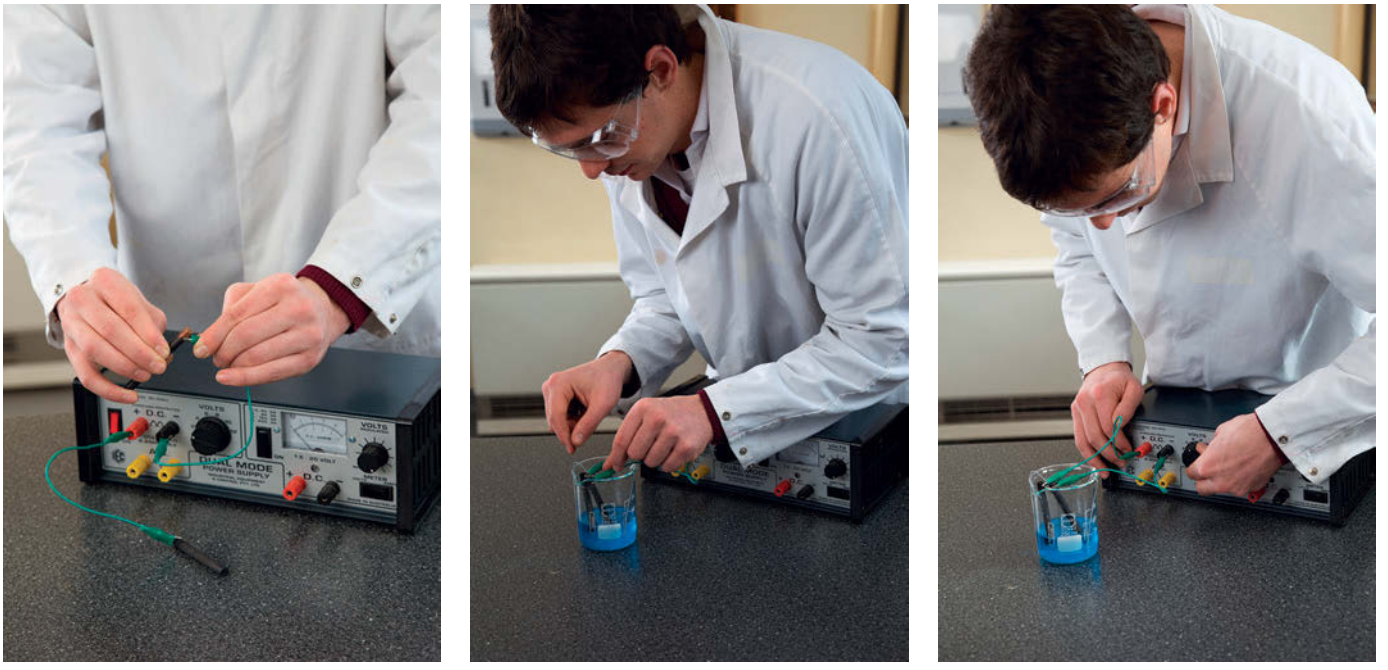


Figure 1 Experimental set-up

9.1 What if the temperature was hotter in the water cycle?

INVESTIGATION

Aim

To design and create a model of the water cycle.

Risk assessment
9.1 What if the temperature was hotter in the water cycle?

Lab tech notes
9.1 What if the temperature was hotter in the water cycle?

What you need

- Large clear plastic bowl
- Plastic wrap
- Small weight
- Smaller container, such as the bottom half of a yoghurt pot
- Water
- Large rubber band or string
- Tape

What to do

1. Place the small container in the middle of the large clear bowl.
2. Fill the bowl with a little water, being careful not to get any in the small container.
3. Cover the bowl with plastic wrap and fix the plastic wrap to the rim of the bowl using either a rubber band or a tight piece of string.
4. Put a small weight on top of the plastic wrap in the centre so that it hangs over, but does not touch, the smaller container.
5. You have now created a portable water cycle. Place your water cycle in partial shade under a tree. Record the time it takes for water to appear in the small container for each model. Record your observations.

Inquiry: What if the temperature was hotter in the water cycle?

- Write a hypothesis for your investigation.
- Which (independent) variable will you need to change to test your hypothesis?
- Which (dependent) variable will you measure and/or observe?
- Name three variables you will keep the same or control.

Results

Record your measurements in an appropriate table.

Discussion

1. Describe the movement of the water as it continues to collect on the plastic wrap.
2. Can any of the water escape from your mini water cycle model? How does this compare with the actual water cycle?
3. Give reasons why your model is or is not an accurate representation of the real water cycle.
4. Describe any modifications that you could make to improve the design of your water cycle model.

Conclusion

What do you know about the water cycle?

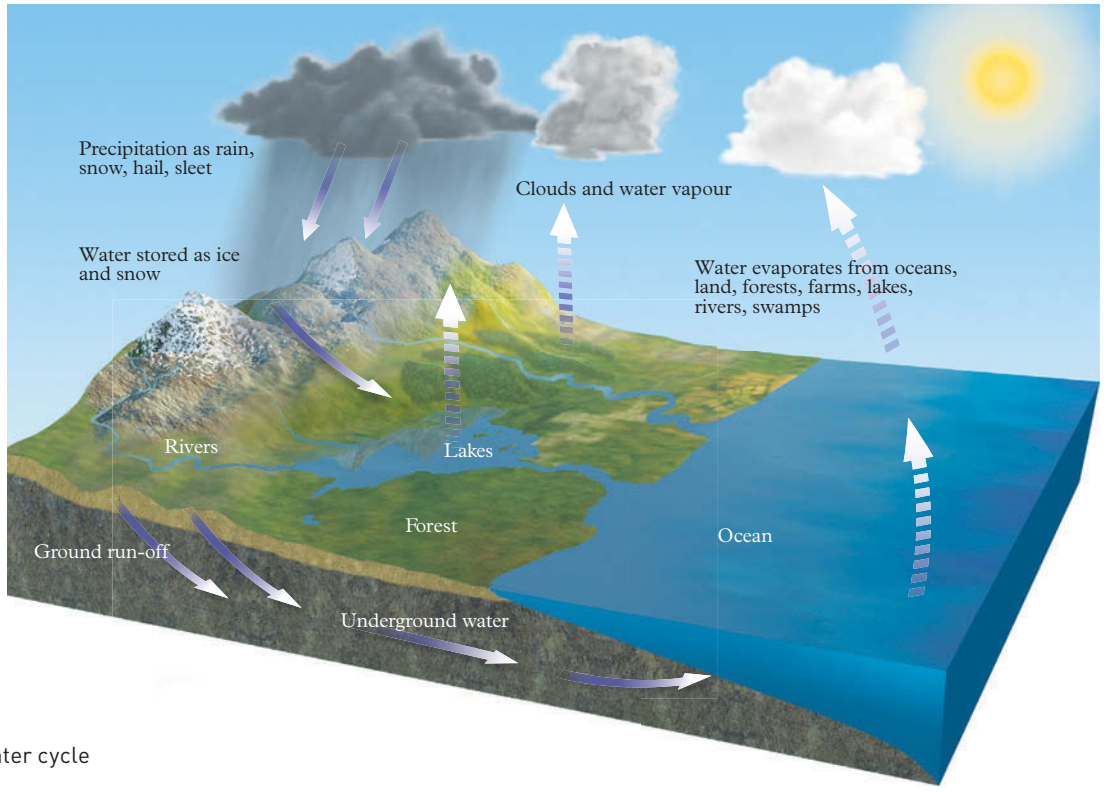


Figure 1 The water cycle

9.3 Can you reduce the evaporation of water in irrigation channels?

CHALLENGE

Design brief

Risk assessment
9.3 Can you reduce the evaporation of water in irrigation channels?

Lab tech notes
9.3 Can you reduce the evaporation of water in irrigation channels?

The Mulwala Canal, in the River Murray region of New South Wales, discharges approximately 9000 million litres of water a day. Over 700 000 hectares of land are irrigated from 2880 kilometres of channels in the area. These open channels allow a lot of water to evaporate before a single drop reaches the plants.

Prepare a report that describes a cost-effective way to prevent the loss of water from the irrigation channels.

Criteria restrictions

- All materials must be available in Australia.
- All prices must be in Australian dollars.

Questioning and predicting

- Research the average width of the channels.
- What materials could you use to replace 1 metre of channel?
- How much would it cost for this material?
- Is there a cheaper material that could do the same job?
- What is the cost of the materials for a 1 kilometre length of channel?
- How much would it cost for 2880 kilometres of channels?

Processing and analysing

1. How did the cost of your design compare with that of other students' designs?
2. Describe one feature of your design that was an improvement on other students' designs.



Figure 1 An open irrigation channel

3. If you were doing this experiment again, what feature would you change? Explain.

Communicating

Present the various stages of your investigation in a formal experimental report.

10.3 Dichotomous key

CHALLENGE

Aim

Risk assessment
10.3 Dichotomous key

Lab tech notes
10.3 Dichotomous key

Using what you have discovered about the characteristics of living things, design your own dichotomous key.

Questioning and predicting

Think about objects that could be sorted into two groups. For example, you might like to use snack foods or items from your pencil case.

Planning and conducting

- What similarities or differences can you find to separate the objects into two groups?
- What other similarities or differences can you find to separate them into further subgroups?
- Keep dividing the group into another two groups until each item is on its own.

Processing and analysing

1. Draw a dichotomous key to show how you grouped the objects.
2. How hard was it to divide your objects into different groups? Could you have used a better group of objects?

Communicating

Swap your dichotomous key with another group. How effective is the dichotomous key constructed by the other group? Ask them to evaluate your key. Which was the best dichotomous key designed in your class? What features made it the best key?

10.4 Can you understand scientific names?

CHALLENGE

Aim

To understand scientific naming conventions.

Risk assessment
10.4 Can you understand scientific names?

Lab tech notes
10.4 Can you understand scientific names?

The scientific names of organisms usually come from Latin (and sometimes Greek) words. Latin was the language of science for many centuries. This enabled scientists who lived in different countries and spoke different languages to communicate their work and discoveries.

The words used in the scientific names of organisms describe physical features, behaviours and even colours. Some examples are given Table 1.

1 Use the information in Table 1 to match the scientific names of the Australian animals with their pictures in Figure 1.
   a *Macropus rufus*
   b *Tachyglossus aculeatus*
   c *Phascolarctus cinereus*
   d *Ornithorhynchus anatinus*
   e *Chlamydosaurus kingii*
2 What do you think a *Macroglossus aculeatus* might look like? On a sheet of A4 paper, sketch this imaginary animal, using the information in Table 1 to help you.

Table 1 Some scientific words and their meanings

Latin or Greek root word	English meaning
Aculeat	Spiny
Arctus	Bear
Anatinus	Duck-like
Cinereus	Grey
Gloss	Tongue
Hynchus	Snout
Macro	Large
Ornitho	Bird
Phascol	Pouch
Pus	Foot
Rufus	Red
Tachy	Fast
Chlamy	Caped
Saurus	Lizard



Figure 1 Matching the scientific names of Australian animals with their pictures

10.6 Dissecting skeletons

SKILLS LAB

Aim

To examine the skeletal structures of three marine organisms.

Risk assessment
10.6 Dissecting skeletons

Lab tech notes
10.6 Dissecting skeletons

CAUTION! Always wear gloves when handling the animals.
The animals must always be on the dissecting board when they are being handled or dissected.
Scalpels are extremely sharp. Use with great care.
If cut, remove gloves and wash the cut under clean water. Apply antiseptic to the cut and cover it with a dressing. Tell your teacher.

What you need

- 1 fish (whole)
- 1 prawn
- 1 squid
- Newspaper
- Dissecting board covered in newspaper
- Dissecting kit
- Pair of vinyl or latex gloves

What to do

1 Observe the external features of the fish.



Figure 1 Observing the external features of a fish

2 Carefully cut the fish in half lengthways so that you can see the internal skeleton.



Figure 2 Cutting the fish in half

3 Observe the skeleton of the fish.
4 Feel the outside of the prawn and then peel it.
5 Cut the prawn in half and observe the insides.



Figure 3 Cutting the prawn in half

6 Feel the outside of the squid and then cut it in half.



Figure 4 Cutting the squid in half

7 Observe the inside of the squid.

Results

Draw labelled diagrams of the skeleton of each specimen.

Discussion

1 Consider the fish.
   a Where is the skeleton of the fish located?
   b What is this type of skeleton called?
2 Consider the prawn.
   a Where is the skeleton of the prawn located?
   b What is this type of skeleton called?
3 Does the squid have a skeleton?
4 In which group of animals – vertebrate or invertebrate – would you place each of the organisms observed? Why?
5 What are you: a vertebrate or an invertebrate?

Conclusion

What types of skeleton are possible?

10.6 Identifying invertebrates

CHALLENGE

Aim

To classify invertebrates using a key.

Risk assessment
10.6 Identifying invertebrates

Lab tech notes
10.6 Identifying invertebrates

What you need

- Magnifying glass or stereomicroscope
- Petri dishes
- Jars with lids
- Tweezers
- Vinyl or latex gloves
- Newspaper

Your teacher may provide prepared samples for you to look at. Complete the classification exercise for each prepared sample.

When completing this task, ensure that you:

- do not touch any animal that might bite or sting – check with your teacher if you are unsure
- use tweezers to pick up the animals
- place any animal immediately in a jar and secure the lid.

What to do

1. Visit a local natural environment (such as a garden, beach, park or pond) and observe invertebrate specimens.
2. Wearing gloves, use tweezers to collect up to 10 invertebrate specimens in separate jars.
3. Use the tabular key in Table 1 to classify the invertebrates into their particular phylum.
4. Use a magnifying glass or stereomicroscope to help you sketch each animal. Write the common name for the animal (if you can) and write down its classification group under the drawing.
5. Return the invertebrates to their natural environment after you have finished.

Table 1 Tabular key for identifying invertebrates

1	Body spongy, with many holes	Poriferan
	Body not spongy	Go to 2
2	Soft body, no shell	Go to 3
	Outside shell or hard cover	Go to 6
3	Many tentacles or arms	Go to 4
	Long body without tentacles	Go to 5
4	Tentacles around the mouth of a sac-like body	Cnidarian
	Arms with suction discs	Mollusc
5	Soft body, large foot	Mollusc
	Worm-like or leaf-like	Nematode, platyhelminth or annelid
6	Proper shell or smooth, hard covering	Go to 7
	Spiny skin with rough covering	Echinoderm
7	Limbs in pairs	Arthropod
	Shell, no segments, large foot	Mollusc



Figure 1 Can you identify the phylum of each of the invertebrates?

10.7 Who are the vertebrates?

CHALLENGE

Aim

To identify different species of vertebrates.

Risk assessment
10.7 Who are the vertebrates?

Lab tech notes
10.7 Who are the vertebrates?

What you need

- A3 paper
- Pencils

What to do

A jellyfish graphic organiser is a good way to show how subgroups make up a whole. It can also be used to list specific examples at the same time.

1 Individually, go around to each of the five sheets of vertebrates and select six animals from each class.
2 On a full page, draw five 'jellyfish' connected to the main group (vertebrates), as shown in Figure 1.

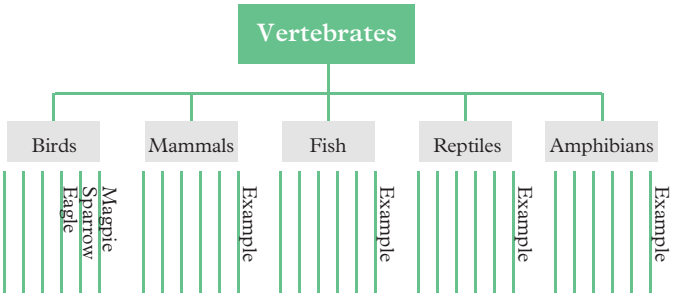


Figure 1 A jellyfish organiser for vertebrates

3 Label each jellyfish with the class name (fish, reptiles, amphibians, mammals and birds).
4 Write a description of the characteristics of each class in the appropriate body of each jellyfish.
5 Place the six animals you selected along the six tentacles on each jellyfish.

10.8 Identifying plants

CHALLENGE

Aim

To observe physical features of plants.

Risk assessment
10.7 Identifying plants

Lab tech notes
10.7 Identifying plants

CAUTION! Allergy alert. Do not handle plants you can't identify. Wear gloves if uncertain.

What you need

- Camera
- Measuring tape
- Pencils
- Paper

What to do

1 Observe and take digital photos of at least five different types of plants from either a local bushland or your garden.
2 Make detailed observations of each plant, including:
   a the height of the plant
   b the width of the plant
   c the shape, smell, texture and size of the leaves (take a close-up photo of the leaves)
   d the position and mount of leaves on the plant.
3 Does the plant produce flowers, seeds or nuts? If so, describe these.
4 Is there anything unusual or special about this plant?
5 Repeat steps 2–4 for all the plants you observed.
6 What features did all the plants have in common?
7 What differences did you observe between the plants? Describe these differences.





Figure 1 Native flora

10.9 Looking at eucalypt adaptations

CHALLENGE

Aim

To examine eucalypt adaptations.

Risk assessment
10.9 Looking at eucalypt adaptations

Lab tech notes
10.9 Looking at eucalypt adaptations

What you need

- Nuts, leaves and bark of a eucalypt

What to do

1 Place the nuts in a 40°C oven for 24 hours to open and shed their seeds. Each of these thick woody capsules contains hundreds of tiny seeds.
   - Why is the seed of the nut protected with such a thick external capsule?
   - What might trigger the release of the seed from the nut?
2 Feel the leaves of the eucalypt. They have a thick cuticle that is effective in preventing water loss.
3 Hold a leaf up to the light or under a binocular microscope. Notice the numerous small dots, which are oil glands in the leaf.



Figure 1 Eucalypt seeds and leaves

   - What is the function of the oil glands in a eucalypt leaf?
4 Have a close look at the bark of the tree. Many eucalypt trees have bark that is thick and fibrous.
   - What are some of the functions of bark?

11.1 Drawing cells

SKILLS LAB

Aim

To observe and draw cells.

Risk assessment
11.1 Drawing cells

Lab tech notes
11.1 Drawing cells

What you need

Several stations are set up around the laboratory with microscopes adjusted to show different kinds of cells.

CAUTION! Do not attempt to adjust any of the microscopes! Ask your teacher or laboratory technician to adjust the microscope if you think it has been bumped or has gone out of focus.

1 Look carefully at each specimen. Write down its name and a sentence that describes what you see.
2 Make a very simple pencil sketch of a single cell that you can see. Draw the outside edge of the cell first, including any bump or unusual shape you notice.
3 Draw two more cells that are close to your original cell. (Do not attempt to draw every cell that you see.)
4 If you can see anything inside the cells (it may only be a dark dot), mark this on your sketch.
5 Label any parts that you can identify.
   - In your opinion, which cells were the most unusual?
   - Which cells had very obvious walls around them?
   - Which cells were the smallest?
   - Which cells were the largest?
   - How did your view through the microscope compare with the images of the cells in Figure 2 in topic 11.3 (see page 187)?
   - Describe some of the difficulties of drawing cells seen through a microscope.



Figure 1 Microscope

11.2 Getting to know your microscope

SKILLS LAB

Aim

To understand how a microscope works.

Risk assessment
11.2 Getting to know your microscope

Lab tech notes
11.2 Getting to know your microscope

What you need

- Compound light microscope
- Microscope slide
- Coverslip
- Small piece of newspaper
- Eyedropper
- Small beaker of water
- Small piece of tissue paper
- Hair (use your own)
- 1 cm sticky tape (transparent)

What to do

1 Always use two hands to carry a microscope – one hand should be around the main part of the instrument and the other should be underneath it.

2 Some microscopes have a built-in lamp. Others have separate lamps that need to be set up so that they shine onto the mirror. Adjust the mirror to project the light through the stage onto the specimen. Do not allow sunlight to shine directly up the column.

3 Place the slide on the stage and then select the objective lens with the lowest magnification first.

4 Cut out two small words from a piece of newspaper.



Figure 1 Use scissors to cut out words from the newspaper.

5 Place the cut out newspaper on the microscope slide and add two drops of water to help it 'stick' to the slide. Place a coverslip on top. This is called a **wet mount**.



Figure 2 Gently lower the glass coverslip down until it is flat.

6 Look from the side and adjust the coarse focus knob so that the objective lens is *just above – and not touching* – the slide. Check which way you must turn the knob to move the objective lens away from the slide.

7 Use the coarse focus knob to bring the specimen into view. Find one letter from the newsprint to focus on.



Figure 3 Carefully adjust the focus of the microscope.

8 Move the slide slightly towards your body and observe what happens.

9 Move the slide slightly to the left and observe what happens.

10 Increase the magnification by rotating the objective lens to a higher magnification.

11 Draw a diagram of the newspaper letter (as a record) using a sharp lead pencil. Never colour or shade areas; if absolutely necessary, use dots or lines instead.

12 Work out the total magnification.

13 Write the magnification next to your sketch.

14 Label and date the sketch.

15 Take the newspaper out and prepare another slide using the tissue paper. Make sure the drop of water is added and the coverslip is placed over the top carefully.

16 Sketch what you see.

17 Repeat with sticky tape and then a hair from your head.

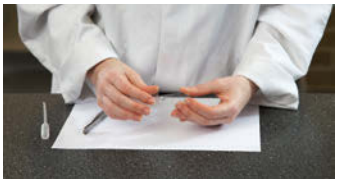


Figure 4 Examine a hair under the microscope.

Discussion

1 Describe what the newspaper letter looks like through the microscope. What does this mean for all things you see through this type of microscope?

2 What features could you see on the tissue paper and sticky tape that you could not see with the naked eye?

3 Use a series of cause-and-effect graphic organisers, similar to that shown in Table 1, to record the results of your experiment when you moved the slide different ways. For example, the cause link may be 'move the slide to the left'. Then write what happened in the effect link.

Table 1 Cause-and-effect graphic organiser

Cause	→	Effect
What did you do to cause the change you observed?		What effect did it have?

11.3 Comparing the size of cells and their parts

CHALLENGE

Aim

To compare the size of different cells.

Risk assessment
11.3 Comparing the size of cells and their parts

Lab tech notes
11.3 Comparing the size of cells and their parts

What you need

- Sheet of poster paper
- Pencil
- 30 cm ruler
- Eraser

What to do

Part A

1 Using the scale of 1 cm = 1 µm, draw a series of circles to represent the average size of various cells and microbes according to the measurements given in Table 1.

Table 1 Average diameters of different cell types

Cell type	Average diameter (µm)
Human cheek cell	30
Human red blood cell	7
Human white blood cell	25
Epidermal plant cell	50
Staphylococcus bacterium (spherical)	1
Escherichia coli bacterium (rod shaped)	3

2 Rank the cells and microbes from smallest to largest.

Part B

Organelles vary in size. Some organelles, such as chloroplasts, are large enough to be visible under the light microscope. Others, such as mitochondria, are usually too small to be visible.

1 Use the measurements given in Table 2 to add a chloroplast and mitochondrion (singular) to your set of diagrams.

Table 2 Sizes of cell organelles

Cell organelle	Average size (µm)
Chloroplast	5 µm long × 1.5 µm wide
Mitochondrion	2 µm long × 1 µm wide

2 Which of the cell organelles in Table 2 are not visible under the light microscope?

3 Viruses are much smaller than even bacterial cells. For example, the influenza virus, which causes the flu, is 0.1 µm in diameter. Add the influenza virus to your diagrams.

11.3A Looking at organelles

INVESTIGATION

Aim

To prepare slides to view the organelles in the cells of a brown onion and an *Elodea canadensis* plant.

Risk assessment
11.3A Looking at organelles

Lab tech notes
11.3A Looking at organelles

What you need

- Onion wedge
- 3 glass slides
- 3 glass coverslips
- Water
- Light microscope
- Methylene blue stain or iodine
- Leaf from an *Elodea canadensis* plant
- Blotting paper

What to do

Onion skin cell – unstained

Light microscopes depend on the light being able to pass through the specimen. When preparing a slide, it is important that the specimen is as thin as possible.



Figure 1 Add a drop of water to the slide and then add a coverslip.

1 Between the fleshy layers of an onion, there are some thin, transparent layers. These layers are one-cell thick. Peel off a layer of this skin and put it onto a microscope slide.
2 Add one drop of water and then gently lower the coverslip so that no air bubbles are trapped.
3 Draw and label what you see. Try to identify the nucleus, which contains the DNA, and the cell membrane and cytoplasm.
4 Keep this slide for use in the next part of the experiment.

Onion skin cells – stained

Stains are often used on specimens because they add contrast to the image. Some highlight a particular feature of the cell.

5 Use another thin layer of onion skin to prepare a second slide, as carried out above.
6 Add a drop of methylene blue stain or iodine instead of the water before lowering the coverslip carefully so that no air bubbles are trapped. Be careful not to get the stain on your skin or clothes because it is very hard to remove.
7 Draw and label what you see. How does the use of the methylene blue stain or iodine change the appearance of the onion cells?

Elodea canadensis cells

8 Pick a small green *Elodea canadensis* leaf and put it onto a microscope slide.
9 Add one drop of water and then gently lower the coverslip so that no air bubbles are trapped.
10 Draw and label what you see. Try to identify the cell membrane and cytoplasm.
11 What other organelle is clearly visible in these cells?

Results

Include your labelled diagrams in this section.

Discussion

1 How does the use of a stain change the image of the onion cells?
2 Both types of cells viewed are from plants. Suggest why there are differences between each of the cell types. (Hint: Consider which part of the plant the cells come from.)
3 It is often difficult to identify the nucleus in the *Elodea canadensis* cells. Suggest a reason for this.
4 The *Elodea canadensis* cells contain another structure that is very prominent. What could be the role of this structure within the cell?
5 Suggest why it is not necessary to stain the *Elodea canadensis* cells.

Conclusion

What do you know about the organelles in onion cells and *Elodea canadensis* cells?

11.3B Measuring cells

INVESTIGATION

Aim

To measure the size of various plant and animal cells using a mini-grid.

Risk assessment
11.3B Measuring cells

Lab tech notes
11.3B Measuring cells

What you need

- Onion cell slide (prepared in Investigation 11.3a)
- Light microscope
- Mini-grid slide or 1 mm graph paper photocopied onto a transparency
- Other various prepared slides, such as human blood, nerve cells, leaf epidermis

What to do

1 Focus the onion cells under the light microscope.
2 Once in focus, estimate the average length and width of one cell in relation to the field of view.



Figure 1 Microscope slides are required for this experiment.

3 Gently remove the slide and insert the slide containing the mini-grid.
4 Each box is 1 mm in length. Determine the length of the field of view by counting how many boxes fit across the light field.
5 Use this measurement to calculate the average length of one onion cell by estimating how many cells fit across the light field.
6 Repeat this process for each of the other prepared slides.

Results

Rank the cells viewed in size from smallest to largest.

Discussion

Does your ranking match Table 1 from Challenge 11.3?

Conclusion

What do you know about the relative sizes of plant and animal cells?

11.4 Plant and animal cells

INVESTIGATION

Aim

To compare plant and animal cells.

Risk assessment
11.4 Plant and animal cells

Lab tech notes
11.4 Plant and animal cells

What you need

- Brown onion
- Microscope slide
- Coverslip
- Iodine in dropper bottle
- Light microscope
- Prepared slide of animal cells

What to do

1 Peel off a very thin piece of brown onion skin so that it looks a bit like cling film.



Figure 1 Peeling off a very thin piece of brown onion skin

2 Place the skin on the microscope slide and add a tiny drop of iodine. This stains parts of the cells to make them easier to see.



Figure 2 Adding a tiny drop of iodine to the microscope slide

3 Place one edge of the coverslip onto the slide and carefully lower it so that no air bubbles are trapped underneath.



Figure 3 Carefully lowering the coverslip

4 Place the slide on the stage.



Figure 4 Placing the slide on the microscope stage

5 Focus the microscope.

6 Draw the cells you observe. Don't forget to label your diagram and write down the total magnification.

7 Remove the slide and place the prepared slide of animal cells under the microscope. Focus the microscope.

8 Draw the cells you observe.

9 Write down the total magnification and label the diagram.

Results

Include your cell diagrams here.

Discussion

1 What is the purpose of staining the onion skin cells?

2 What kind of living thing did the onion skin come from?

3 Compare the two sketches you have prepared with the images of plant and animal cells in Figure 2 in topic 11.3 (see page 187)? List any differences and similarities.

4 Use the Venn diagram in Figure 5 below to show how plant and animal cells are similar and how they are different.

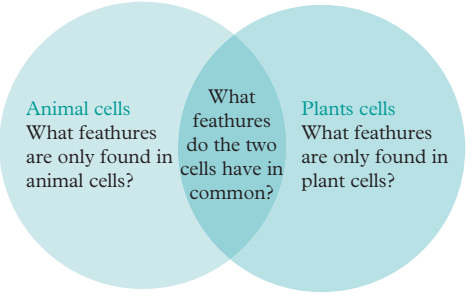


Figure 5 What are the similarities and differences between plant and animal cells?

Conclusion

What do you know about plant and animal cells?

11.5 Modelling mitosis

CHALLENGE

Aim

To model mitosis.

Risk assessment
11.5 Modelling mitosis

Lab tech notes
11.5 Modelling mitosis

What you need

- 4 long balloons
- Permanent marker

What to do

1 Blow up one balloon and label it 'parent cell'.
2 Blow up the second balloon to represent the parent cell becoming larger in preparation for mitosis.
3 Use the two remaining balloons to represent the two daughter cells that result from cell division. Label each of these cells as 'daughter cell'.

Discussion

1 How would you represent a cancerous cell?
2 How would you represent apoptosis in a balloon cell?



Figure 1 This experiment requires balloons.

12.2A Locating the stomata of a leaf

CHALLENGE

Aim

To examine the stomata of a leaf.

Risk assessment
12.2A Locating the stomata of a leaf

Lab tech notes
12.2A Locating the stomata of a leaf

What you need

- Clear fingernail polish
- Fresh plant leaf
- Clear sticky tape
- Glass slide
- Microscope

What to do

1 Paint a thick patch of clear nail polish in the underside of the leaf and allow to dry.
2 Place a piece of the clear sticky tape over the dried nail polish.
3 Gently peel the sticky tape off the leaf, removing the nail polish patch from the leaf's surface.
4 Tape the peeled section of leaf onto the glass slide.
5 Examine the slide under the microscope and locate a stoma (plural 'stomata').
6 Draw a labelled diagram of the stoma.

Discussion

1 What function do stomata have in a plant?
2 Was the stoma you located open or closed?
3 Refer to the time of day and the location of the plant to explain why the stoma on your plant was open or closed.



Figure 1 Mango leaf

12.2B Locating the xylem and phloem in a stem

CHALLENGE

Aim

To observe the xylem and phloem in celery.

Risk assessment
12.2B Locating the xylem and phloem in a stem

Lab tech notes
12.2B Locating the xylem and phloem in a stem

What you need

- 500 mL beaker
- Water
- Beaker
- Blue or red food colouring
- Fresh stick of celery with leaves still attached.
- Scalpel
- Cutting board
- Permanent marker
- Magnifying glass

What to do

1. Add 200 mL of water to the beaker.
2. Add 15 drops of food colouring to the water.
3. Cut the bottom 10 cm off the celery.
4. Place the top half of the celery in the beaker of coloured water.
5. Mark the water level with a permanent marker. Leave for 2–3 days.
6. Remove the celery from the water and use the scalpel to cut a horizontal transverse section of the celery stalk.
7. Locate the pathway that the coloured water moved through the celery. Draw a labelled diagram of the celery cross-section.

Discussion

1. What did you notice about the amount of water in the beaker after 2–3 days?

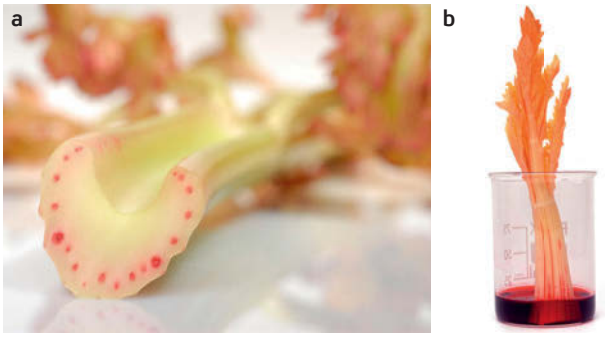


Figure 1 a The dye marks the path the water takes from the roots. **b** As water evaporates from the leaves, the dye water replaces it.

2. Use the term 'transpiration' to explain your answer to the previous question.
3. What is the name of the pathway that moved the coloured water through the celery?
4. How is this similar to the circulatory system in humans? How is it different?

12.2C Modelling root cells

CHALLENGE

Aim

To model root cells.

Risk assessment
12.2C Modelling root cells

Lab tech notes
12.2C Modelling root cells

What you need

- 15 cm dialysis tubing
- Distilled water
- 5 mL of 5% starch solution
- Scales
- 200 mL beaker

What to do

1. Soften the dialysis tubing by running distilled water over the outside of it.
2. Tie a knot in one end of the tubing.
3. Add 5 mL of starch solution to the tubing.
4. Seal the open end by tying a knot.
5. Wash the outside of the tubing with distilled water.
6. Pat the outside of the tubing dry and determine its weight using the scales.
7. Place the tubing in the beaker. Add 100 mL of distilled water.
8. Leave overnight.
9. Remove the dialysis tubing from the water and carefully pat dry.
10. Determine the weight of the dialysis tubing.

Discussion

1. What was the difference in weight of the dialysis tube with starch before and after soaking in water?
2. What caused the change in the weight of the tubing?
3. What is osmosis?
4. Use the term 'osmosis' to explain how the dialysis tubing is similar to the cells in a root.

12.2 Factors that affect transpiration

INVESTIGATION

Aim

To determine the factors that affect the transpiration of water from plants.

Risk assessment
12.2 Factors that affect transpiration

Lab tech notes
12.2 Factors that affect transpiration

Materials

- 200 mL measuring cylinder
- Water
- 2 fresh celery stalks with leaves still attached

What to do

1. Add 100 mL of water to the measuring cylinder.
2. Cut the bottom 10 cm off the celery and trim so that the end of it fits into the measuring cylinder.
3. Place the top half of the celery in the measuring cylinder.
4. Mark the water level with a permanent marker. Leave for 2–3 days at room temperature.
5. Measure how much water has been lost by the celery stick.

Inquiry: Choose one of the questions below to investigate

- What if the celery was placed in sunshine?
- What if the celery was placed in wind? (A fan may be used.)
- What if the celery was placed in a humid environment? (A large clear plastic bag may be placed over the celery.)

Answer the following questions in relation to your inquiry.

- Write a hypothesis for your question.
- Which (independent) variable will you change from the first method?
- Which (dependent) variable will you measure/observe?
- Name three variables you will keep the same/control.

Results

Record your observations and measurements in a table.

Discussion

1. What is transpiration?
2. What factors would you expect to affect transpiration?
3. Did your results support your hypothesis? Use evidence from your results to support your answer.
4. How could you use your results to support the plants in your garden?

Conclusion

What do you know about the factors that affect transpiration?



Figure 1 Fresh celery stalks are required for this experiment.

12.3 Flower dissection

INVESTIGATION

Aim

To examine the main parts of a flower.

Risk assessment
12.3 Flower dissection

Lab tech notes
12.3 Flower dissection

CAUTION! Knives and scalpels are very sharp. Always cut away from hands.

What you need

- Newspaper
- A flower (you can dissect any type of flower available; lilies and fuchsias are good examples)
- Scalpel blade or sharp knife
- Hand lens

What to do

1 Place the newspaper on the bench.
2 Cut the flower off the stalk.
3 Observe the flower. Identify the main parts of the flower from Figure 1.
4 Draw a labelled diagram of the flower.
5 Gently remove the sepals and petals.
6 Look for the stamen with anthers at the top. The anthers hold the pollen. You should be able to dust some pollen onto your finger.
7 Cut off the male parts at the bottom of the petal.
8 Observe the female part of the flower. It has the stigma at the top and the ovary at the bottom.
9 Cut the ovary lengthwise. In it you will see tiny white scales, which are the ovules. When the ova inside the ovules are fertilised by the pollen, they will grow to become seeds and the ovary will grow to become the fruit.
10 Draw a labelled diagram of the ovary.
11 Carefully place knives and scalpels into a container. Clean up your bench by wrapping the flower parts in the newspaper. Wash your hands.

Results

Draw labelled diagrams of the male and female parts of the flower.

Discussion

1 What colour is the filament (the stem of the stamen)? Why do you think this is?
2 How easy was it to clean the pollen from your fingers? Is this good for the flower?
3 How were the male and female parts arranged to encourage pollination? Explain.
4 Do you think the flower is more likely to be self-pollinated or cross-pollinated? Explain.
5 Do you think pollination is more likely to be by wind, water or animals? Explain.

Conclusion

What do you know about the parts of a flower?

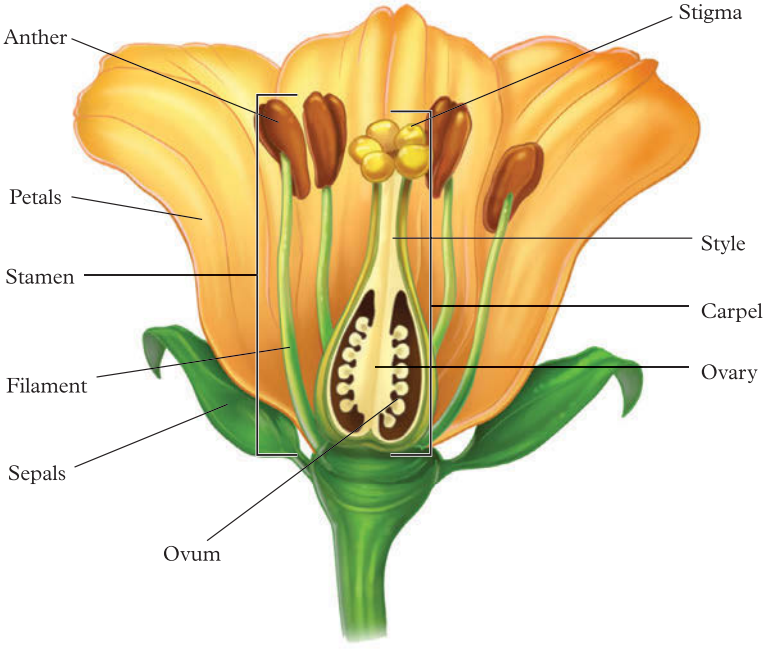


Figure 1 The structure of a flower

12.4A Digesting protein

INVESTIGATION

Aim

Risk assessment
12.4A Digesting protein

Lab tech notes
12.4A Digesting protein

To investigate the function of pepsin, an enzyme found in the stomach, and to establish the conditions under which pepsin functions best.

Egg white is being used as the source of protein in this experiment.

CAUTION! Some students may have egg allergies. Dangerous chemicals are involved. Pour carefully, clean up all spills immediately and rinse your hands if you come into contact with any chemicals.

What you need

- 4 test tubes
- Test tube rack
- Permanent marker
- Hard-boiled egg white
- 10 mL measuring cylinder
- 1% pepsin solution
- Water
- Dilute hydrochloric acid (1 M HCl)
- Dilute sodium hydroxide solution (0.1 M NaOH)
- 1 mL pipette
- Rubber band
- Incubator (37°C)

Safety

Bring the materials to the test tubes, rather than risking them being dropped when carrying them around the room.

What to do

1. Label four test tubes 'A', 'B', 'C' and 'D' with permanent marker.
2. Collect some hard-boiled egg white. Cut four cubes of approximately 1 cm^3 ensuring that the cubes are the same.
3. Put a cube of egg white in each tube.
4. Add 10 mL pepsin to test tubes A, C and D.
5. Add 10 mL water to test tube B.
6. Add 10 drops of HCl to test tubes A and B.
7. Add 10 drops of 0.1 M NaOH to test tube D.
8. Add 10 drops of water to test tube C.
9. Bind the four test tubes with a rubber band and label the bunch with your initials.
10. Incubate for at least 24 hours at 37°C.

Results

Record the ingredients for each tube with a tick or cross in the table below. Provide very brief statements to describe your observations of the results.

Tube	Egg white	Pepsin solution	HCl	NaOH	Water	Results
A						
B						
C						
D						

Discussion

1. This experiment is a 'controlled' experiment. What do you understand this term to mean?
2. How can combining the class's data improve the accuracy of the interpretations?
3. Construct a sentence to explain how the comparison of test tubes relates to the human stomach for A and B, A and C, and A and D.
4. In which test tube(s) has the protein been almost completely digested? How do you know?
5. Has the pepsin digested the protein? If so, how can you be sure?
6. What are enzymes?
7. Does HCl digest the protein by itself? How do you know?
8. Complete the following word equations to show what has happened in this experiment.
   - Tube A: protein + _____ + _____ → amino acids
   - Tube B: water + _____ + _____ → _____
   - Tube C: pepsin + _____ + _____ → _____
   - Tube D: pepsin + _____ + _____ → _____
9. Why does the body digest protein? What would happen to the protein after it has been digested?
10. Predict what would happen if this experiment was repeated with carbohydrates instead of protein, leaving the rest of the experiment exactly the same.

Conclusion

What do you know about the function of pepsin and the conditions under which pepsin functions best?

12.5 Heart dissection

INVESTIGATION

Aim

To explore the structure and function of a heart.

Risk assessment
12.5 Heart dissection

Lab tech notes
12.5 Heart dissection

CAUTION! Knives and scalpels are very sharp. Always cut away from hands.

What you need

- Sheep, cow, ox or pig heart
- Scalpel
- Dissecting board
- Newspaper
- Dissecting probe
- Forceps

What to do

1 Examine the outside of the heart and identify the left and right sides. Your fingers will work better than a probe for that.

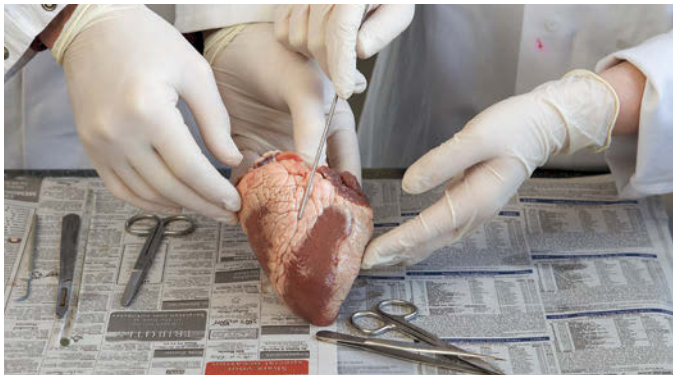


Figure 1 Identify the right and left sides of the heart.

2 Use your fingers to feel the right side of the heart. Compare the thickness of the right and left sides. Feel the muscle in the centre of the heart.

3 Using a scalpel, cut open the right atrium and right ventricle. Pull back the wall and look inside to see the atrium and the ventricle. The ventricle is the chamber closest to the pointed end of the heart. The white tendons hold the valves in place.

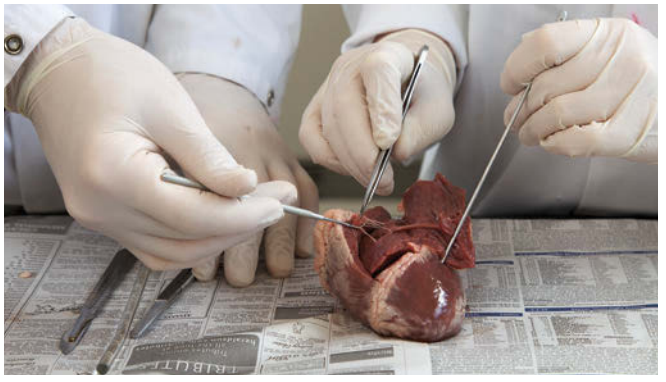


Figure 2 Compare the thicknesses of the right and left ventricles.

4 Push a dissecting probe or your finger out through the artery leading from the right ventricle.

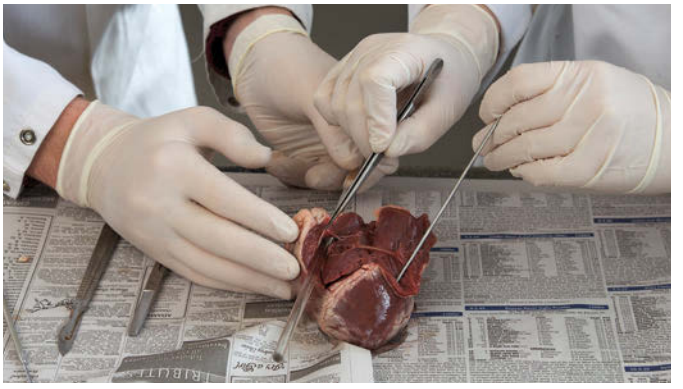


Figure 3 Use the dissecting probe to identify the arteries.

5 Cut open the left side of the heart. Locate the atrium, ventricle and tendons holding the valves.

6 Push a dissecting probe or your finger out through the artery leading from the left ventricle.

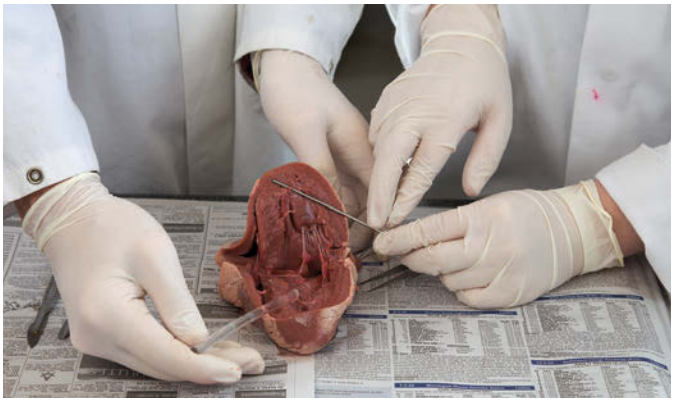


Figure 4 Identify the artery leaving the left ventricle.

Results

Include labelled diagrams and observations here.

Discussion

1 What is the artery from step 4 called?

2 What is the artery from step 6 called?

3 How does the thickness of this artery wall compare with the thickness of a vein wall?

4 How does the thickness of ventricle walls compare with that of atrial walls?

5 How can you explain the difference between the left and right ventricle walls?

Conclusion

What do you know about the structure and function of the heart?

12.5 Modelling blood flow

CHALLENGE

Aim

To model blood flow.

Risk assessment
12.5 Modelling blood flow

Lab tech notes
12.5 Modelling blood flow

What you need

- Scissors
- Plastic cups
- 1 thin straw
- Play dough
- 1 thick straw
- Food colouring
- Water
- Large tray
- Timer

What to do

1. Use the scissors to poke a straw-sized hole through the side of the cup.
2. Place the thin straw through the hole of the cup, making sure the straw is not being squeezed.
3. Use play dough to seal around the hole so that there are no leaks. Water should only be able to escape through the straw.
4. Cut the straw so that it is 5 cm in length.
5. Repeat this for the thick straw, making sure the straw is placed in approximately the same height from the cup's base.
6. Place the cups in the tray and fill both cups with equal amounts of coloured water.
7. Time how long each cup takes to become empty.

Discussion

1. What effect did narrowing the straws have to the effectiveness of water flow?
2. What complication of the circulatory system does this model reflect?
3. Treatment for this complication involves inserting a small balloon into the blood vessel and allowing it to stretch the vessel so that it becomes wider. How will this help the patient?

12.8A Measuring your lung capacity

CHALLENGE

Aim

To measure lung capacity.

Risk assessment
12.8A Measuring your lung capacity

Lab tech notes
12.8A Measuring your lung capacity

What you need

- A large 5 L container with volume markings on the side. No lid required.
- Access to a large sink or tub
- 1 m of tubing

What to do

1. Place 10 cm of water in the bottom of a sink.
2. Fill the container with water.
3. Tip the container upside down in the sink so that the opening is submerged. This will prevent the water leaving the container.
4. Place one end of the tubing under the opening of the container.
5. Take a deep breath and blow as much as you can into the tubing. As you blow air into the container, the water should be pushed out the bottom.
6. Measure how much air you are able to blow out of your lungs into the container.

Discussion

1. Can you repeat the results by performing your experiment two more times?

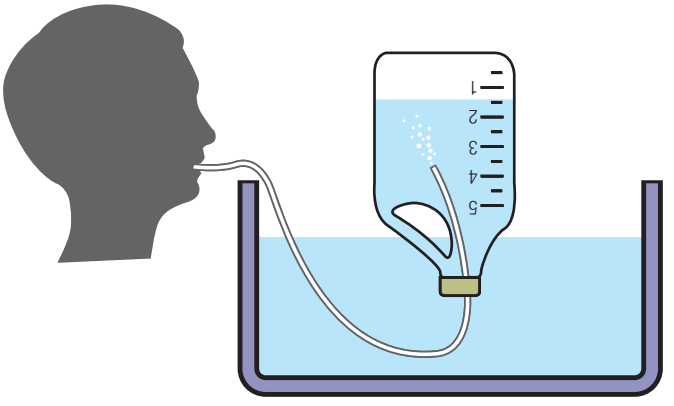


Figure 1 Measuring the capacity of your lungs

2. Is there a chance your results could have been affected by something else? For example, do you have a chest infection or other illness that has impacted on your lung capacity?
3. Compare your results with others in the class. Can you notice any relationships between height of the person and their lung capacity?

12.8B Fish dissection

INVESTIGATION

Aim

To examine the respiratory system in a fish.

Risk assessment
12.8B Fish dissection

Lab tech notes
12.8B Fish dissection

CAUTION! Knives and scalpels are very sharp. Always cut away from hands. When cutting the fish be careful of the fins as they may have spikes and are very sharp.

What you need

- A fish, complete with internal organs, from a fishmonger or market
- Dissection tools

What to do

Part A: Identifying key organs

Use your dissection skills to open the abdomen and head of the fish and record your observations of the internal organs using labelled diagrams.

Discussion

1. What do you notice about the arrangement of the organs?
2. Are the systems clearly separated or are they intertwined?
3. Are certain organs a darker red colour than others?
4. What might this tell you about their blood supply?
5. What might this tell you about their importance?

Part B: Identifying and removing the gills

Identify and remove the gills of the fish. Reflect on the significant features of our lungs that make them such effective gas exchange organs.



Figure 1 Identifying the key organs in the dissected fish

Discussion

1. Do fish gills have similar features to lungs?
2. Do they have different forms to achieve the same function?

14.2 Studying food webs

CHALLENGE

Aim

To observe the food webs in your local area.

Risk assessment
14.2 Studying food webs

Lab tech notes
14.2 Studying food webs

What you need

- Metre-long sticks, rulers or quadrats
- Poster board
- Markers
- Photographs of ecosystems

What to do

1. Think about what you know about food webs in your area. Come up with a list of at least 10 components within these food webs. Do some areas support more life than others?
2. Select two 1 m^2 areas in your backyard, schoolyard or neighbourhood to study. The study areas should be near each other but in two different habitats, such as on a footpath and on some grass, or just inside a forest and in a clearing.
3. Observe and record all organisms above and within these study areas.
   - Which organisms are producers?
   - Which organisms are consumers?
   - How do the numbers (of individuals and species) of producers and consumers compare?

14.3 Exploring leaf litter

CHALLENGE

Leaf litter is the dead and rotting leaves that lie on the ground under trees and in gardens. Leaf litter helps protect soil and is home to many tiny, fragile invertebrates that work together to keep the soil in good condition.

Risk assessment
14.3 Exploring leaf litter

Lab tech notes
14.3 Exploring leaf litter

CAUTION! Before you start, ask your teacher about any bull ants, poisonous spiders or centipedes that are found in your area. There may be some animals that could bite you. If in doubt, leave the animals alone and ask your teacher.

What you need

- Old newspaper
- Gloves
- Specimen jars with lids
- Wet paintbrush
- Hand lens
- Pen
- Paper

What to do

1 Find an undisturbed area approximately 50 cm long by 50 cm wide. Work only in this area.

2 Lift up the leaves slowly. Use your wet paint brush to pick up the tiny animals and gently place them in the specimen jar. Do not crush. Put lid on.

3 Make a list of the animals you find. Include on a separate list any eggs, cocoons, larvae or types of fungi you find.

4 Return the animals to the place where you found them.
   - Why is it important to know something about the animals you are likely to find before looking for them?
   - Why should you return animals to the place where you found them?
   - A leaf litter community doesn't contain any producer organisms, like healthy green plants. What is the energy source for this community?

14.3 What if water was filtered through a pot with native grasses?

INVESTIGATION

Aim

To find out how effective natural systems can be at filtering water.

Risk assessment
14.3 What if water was filtered through a pot with native grasses?

Lab tech notes
14.3 What if water was filtered through a pot with native grasses?

What you need

- 1 medium-sized plastic pot
- 2 plastic buckets
- Stopwatch
- Gravel
- Sand
- Soil
- Plants
- Mixture of castor oil, dirt, small pieces of paper, water, salt water
- Native grasses

What to do

1 A few weeks in advance, prepare one plastic pot with a layer of gravel, then sand and finally dirt. Plant some native grasses in this pot. You will need to wait until the grasses have established themselves in the pot before proceeding with this experiment. (Hint: You should be able to see the roots of the plant in the bottom of the pot.)

2 Mix the castor oil, dirt, finely shredded paper, salt and any other materials you wish to include in a bucket of water. The mixture should be very cloudy and have an odour.

3 Slowly pour an equal amount of the mixture through the pot, using the second bucket to collect the solution that filters out of the base of the pot. Time and record the flow of solution out of the base of the pot. Also take note of the odour of the solution.

Inquiry: What if the water was filtered through a pot with no plant?

- Write a hypothesis for your question.
- Which (independent) variable will you change from the first method?
- How will you measure if the absence of the plant makes a difference to the filtering of the water?
- How will you make sure that all parts of the plant are removed?
- What other variables will you need to control?

Results

Create a table to record the time taken for the solution to flow out of the base of each pot. Include a description and/or photograph of the appearance of the solution before and after it has gone through each pot.

Discussion

1 Did the solution flow out of each pot at a different rate? Suggest a reason for any differences observed.

2 Compare the cloudiness of the final solutions. Suggest a reason for the differences observed.

3 Compare the odour of the filtered solution with that of the original mixture.

Conclusion

How effective are natural systems at filtering water?

14.5 Microbes all around

INVESTIGATION

Aim

To determine the effectiveness of detergents in killing or restricting bacterial growth.

Risk assessment
14.5 Microbes all around

Lab tech notes
14.5 Microbes all around

CAUTION! Most human pathogenic bacteria and fungi (those that are potentially harmful to humans) grow optimally at 37°C. For this reason, samples should be sealed with paraffin wax or tape prior to incubation and destroyed immediately after analysis.

What you need

- 3 Petri dishes (containing nutrient agar)
- gloves and waste plastic bag (for dirty swabs)
- 2 sterilised swabs
- Paraffin wax strips
- Incubator

What to do

1 Two agar plates are to be used for growing microbes and the third is the negative control plate. The negative control plate should not be opened at any stage of the activity; it must be incubated alongside the sample plates.
2 Decide on a site around the school to be tested for microbes.
3 Keep the swabs sterile (germ free) until you reach the site.
4 Rub the swab over the site and then gently rub it across the surface of the agar in both directions. Take care not to damage the surface of the agar.
5 Quickly place the lid on the plate, seal it with a wax strip and then incubate it, along with the control plate, at 37°C for 2–3 days.
6 Collect all used swabs into a waste plastic bag and return to the laboratory for safe disposal.

Inquiry: What if a detergent was spread over the surface of the agar plate?

- Choose a detergent that you would like to test.
- Write a hypothesis for your experiment.
- Which (independent) variable will you change from the first method?
- How will you know if the detergent is effective in killing or restricting bacterial growth? (This is your dependent variable.)
- List three variables you will keep the same/control between the three plates.
- Record your observations in a table.
- At the end of the activity, dispose of the agar plates appropriately.

Discussion

1 Describe the growth on your sample plates after the incubation period. A labelled diagram may assist your description. Did you observe the growth of both bacteria and fungi? What were some of the differences between them?



Figure 1 Carefully wipe the swab over the agar plate.

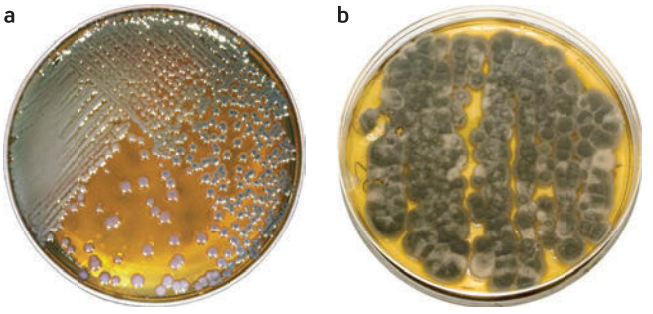


Figure 2 a Bacterial colonies growing on an agar plate. **b** Fungi tend to have a dusty or fuzzy appearance.

2 If your sample plate showed evidence of bacterial growth, do you think that there was more than one type of bacteria present? Justify your response.
3 Was your detergent effective in controlling bacterial growth?
4 Explain why it is important that both the swab and plate are sterile and only exposed to the environment for a short period while collecting the sample.
5 If the negative control plate was sterilised appropriately prior to the beginning of this activity and then incubated alongside the sample plate, it should have showed no bacterial or fungal growth. Explain the purpose of the negative control plate.

Conclusion

What do your results conclude about the effectiveness of your detergent?

15.1 Comparing states of matter

INVESTIGATION

Aim

To investigate the characteristics of solids, liquids and gases.

Risk assessment
15.1 Comparing states of matter

Lab tech notes
15.1 Comparing states of matter

What you need

- Clamp
- 250 mL beaker
- Water
- Food colouring
- 3 different shaped containers
- Plastic syringe
- Stopper to fit syringe
- 100 mL beaker
- Electronic balance
- Balloon

What to do

1. Complete the table in the 'Results' section below as you work through the method.
2. Examine the clamp and record its mass, shape, ability to be compressed and other data in the table.
3. One-third fill the 250 mL beaker with water. Add two drops of food colouring and mix carefully.
4. Pour the coloured water, in turn, into the three other containers. Record what happens to the shape of the water in each of the containers.
5. Half-fill the syringe with water and invert it onto the stopper on the bench as shown in the diagram. Make sure that the syringe is well sealed before compressing it. Record whether water can be compressed (that is, take up less volume).
6. Set the empty 100 mL beaker on the electronic balance and press the 'TARE' button. Pour in the water from the syringe and measure the mass of the water.
7. Draw the syringe full of air and invert the syringe onto the stopper. Compress the syringe. Record whether air is compressible and takes the shape of the syringe.
8. Record the mass of the empty balloon and then blow it up. Tie off the end and weigh the balloon again, this time with air in it. Subtract the mass of the empty balloon from that of the blown-up balloon to calculate the mass of the air inside the balloon. Record whether the air takes the shape of the balloon.

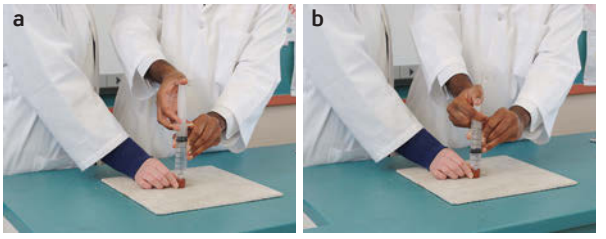


Figure 1 Testing the compressibility of air **a** before and **b** after depressing the plunger on the syringe.

Results

Matter	State of matter	Mass (g)	Able to take shape of container?	Able to be compressed?	Other characteristics observed
Clamp	Solid				
Water	Liquid				
Air	Gas				

Discussion

1. Which substances had a measurable mass?
2. Did each substance take up space? Was there any variation in the shapes each substance was able to take?
3. Which states of matter took on the shape of their containers?
4. Which state of matter can be compressed into a smaller space? Describe what happened.

Conclusion

Write a short paragraph to describe what you know about the states of matter.

15.2 Modelling matter

CHALLENGE

Aim

To model the three states of matter.

Risk assessment
15.2 Modelling matter

Lab tech notes
15.2 Modelling matter

What you need

- Items such as table tennis balls, coins, lollies, marbles and pieces of modelling clay

What to do

Make a model of the three states of matter, using objects to represent the particles. Suitable items include table tennis balls, coins, lollies, marbles and pieces of modelling clay. Alternatively, you can use objects from home.

Discussion

1 How well do your particles represent the characteristics of real particles?
2 How well does your model represent the position and arrangement of real particles?
3 Can your model represent the movement of real particles?
4 How well could your model help explain the properties of real substances, such as the melting of solids?
5 Is there a better material (or different objects) that you could use to represent the particles? How would this improve the model?



Figure 1 A model representing matter can be made using any materials you have availalbe at home.

15.3 Making a cuppa

CHALLENGE

Aim

To observe diffusion.

Risk assessment
15.3 Making a cuppa

Lab tech notes
15.3 Making a cuppa

What you need

- 2 large beakers
- Hot water
- Cold water
- 2 tea bags

What to do

1 Fill one beaker with hot water and the other with cold water.
2 Allow the beakers to sit still for a few minutes so that the movement of the water inside them is reduced.
3 Place a tea bag into each beaker. Brown colour from the tea leaves seeps into the water and then diffuses throughout the beaker of water.
4 Compare the speed of diffusion in hot and cold water.

Discussion

Compare the speed of diffusion in hot and cold water based on your observations.



Figure 1 Cup of tea

15.5 The density den

INVESTIGATION

To calculate the density of a substance, you first need to know its mass and volume. The most appropriate units for the substances you will be working with are grams (g) for mass and millilitres (mL) or cubic centimetres (cm^3) for volume. Millilitres tend to be used for the volume of liquids, whereas cubic centimetres are used for solids.

Note that 1 mL is the same as 1 cm^3. Therefore, grams per millilitre (g/mL) is the same as grams per cubic centimetre (g/cm^3).

Three density experiments are set up around the laboratory. In two experiments, you will measure density in grams per millilitre (g/mL) to make it easier to work with liquids.

STATION A

Aim

To measure the density of liquid water.

Risk assessment
15.5 The density den

Lab tech notes
15.5 The density den

What you need

- 10 mL measuring cylinder
- Electronic balance
- Water
- Calculator
- 50 mL measuring cylinder

What to do

1. Complete the table below and use it to record your measurements.
2. Measure the mass of the 10 mL measuring cylinder. Record its mass in grams.
3. Remove the measuring cylinder from the balance and add 6.0 mL of water to it.
4. Measure the mass of the cylinder and water. Calculate the mass of the water by subtracting the mass of the cylinder from the combined mass of the cylinder and water.
5. Calculate the density of the water and record your answer. (Don't forget the units!)
6. Repeat the experiment with the 50 mL measuring cylinder and 20 mL of water. Calculate the density of the water.
7. To obtain a third measurement of the density of water, choose one of the two measuring cylinders and any amount of water. Measure the mass of the water and its volume. Calculate the density of the water.

Results

List the three results you obtained for the density of water. Calculate an average value.

Discussion

1. The standard value for the density of water is 1.00 g/mL at 25°C. How does your average value compare with this?
2. What could have caused your results to differ from the standard value of the density of water?
3. When you calculate the density of water, does the amount of water used make any difference? Explain the reasons for your answer.
4. Why do scientists repeat experiments?

Type of cylinder	Mass of measuring cylinder (g)	Volume of water (mL)	Mass of measuring cylinder and water (g)	Mass of water (g)	Density of water = mass/volume(g/mL)
10 mL measuring cylinder		6			
50 mL measuring cylinder		20			
					Average =

STATION B

Aim

To measure the density of regular-shaped blocks made from different materials.

What you need

- Several blocks made from different substances (such as wood, polystyrene, lead, zinc)
- Ruler
- Electronic balance
- Calculator

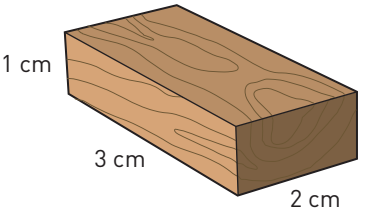


Figure 1 Calculating the volume of a regular-shaped block

What to do

1 Complete the following table and measure and record the mass of each of the blocks.

2 Calculate the volume of each block. (An example has been done for you.)

Results

Rank the blocks in order from least dense to most dense.

Substance	Length (cm)	Width (cm)	Height (cm)	Volume (cm^3)	Mass (g)	Density (g/cm^3)
Glass	4	3	2	$4 \times 3 \times 2 = 24\ cm^3$	48	$48 \div 24 = 2\ g/cm^3$

STATION C

Aim

To measure the density of irregular-shaped objects.

Materials

- 4 different objects (such as spatula, a small rock, a lump of plasticine and an object of your choice) that each fit into the measuring cylinder
- Electronic balance
- 100 mL measuring cylinder

Method

1 Fill in the following table as you complete this task.

2 Measure the mass of the first object. Record the mass, in grams, in your table.

3 Use the displacement method to work out the volume of the object. Approximately half-fill the measuring cylinder. To calculate the volume of the object, subtract the volume of water in the cylinder before the object was added from the volume after the object was added.

4 Calculate the density of the object.

5 Repeat the experiment with the remaining objects.

Results

Include your table here.

Discussion

1 What were some of the difficulties you had using the displacement method for calculating density?

2 What were some advantages of using the displacement method for measuring volume?

3 How does the density of water compare with the densities of the other objects you measured? Use the results from all the experiments to rank the objects from lowest to highest density.

4 How would our world be different if the density of water was five times as much (that is, 5 g/mL)? How would this affect your mass, your life and the world generally?

Conclusion

What do you know about how density affects the behaviour of objects?

Object	Mass (g)	Volume before (mL)	Volume after (mL)	Volume of object (after – before, in mL)	Density (g/mL)

15.6A Effect of heat

INVESTIGATION

Aim

To determine the effect of heat on solids, liquids and gases.

Risk assessment
15.6A Effect of heat

Lab tech notes
15.6A Effect of heat

CAUTION! Wear safety glasses and a lab coat, and tie long hair back, when using a Bunsen burner.

STATION 1: HEATING A SOLID

What you need

- Ball and ring apparatus
- 2 × 250 mL beakers
- Timer
- Hot tap water
- Ice

What to do

1. Look at your ball and ring. Try passing the ball through the ring before heating and cooling. Record your observations.
2. Half-fill a 250 mL beaker with hot tap water. Place your ball in the hot water for 5 minutes. Keep the ring away from the hot water.
3. Try passing the ball through the ring. Record your observations.
4. Half-fill the other beaker with cold tap water and add ice. Put the ball in the iced water and leave it for 5 minutes. Keep the ring away from the iced water.

Results

Record your observations.

Discussion

1. What happened to change the size of the metal ball?
2. Use the kinetic theory of matter to explain what was happening to the particles in the solid when heat was applied.
3. Do objects return to their original size when they cool to their original temperature?

STATION 2: HEATING A LIQUID

CAUTION! Make sure the apparatus is not left unattended. The dye and water will spurt out the top of the glass tube if allowed to.

What you need

- 100 mL conical flask
- Food colouring
- Water
- Rubber stopper to fit tubing
- Felt-tipped pen
- Bunsen burner
- Heating mat
- Gauze mat
- Narrow glass tubing
- Tripod
- The flask and its contents may be hot. Allow all equipment time to cool before handling it.

What to do

1. Put two drops of food colouring in the flask and fill the flask right to the top with water.
2. Place the stopper fitted with the tube in the flask. Some water will rise up the tube. Using the felt-tipped pen, mark this first level on the tube.
3. Place the flask on the gauze mat on the tripod and heat gently.
4. After a few minutes of heating, turn off the Bunsen burner. Mark the level of the water in the tube again.
5. Watch what happens to the level of the water as it cools.

Results

Record your observations.

Discussion

1. Describe what happened to the water in the tube as the flask was heated.

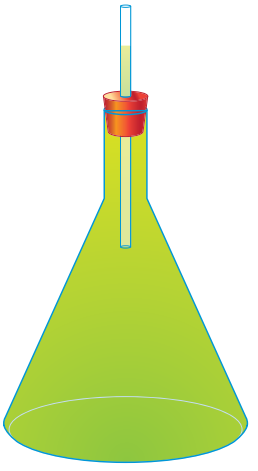


Figure 1 Experimental set-up to show the expansion of a liquid after heating

2. What happened to the level of the water in the tube as the water cooled?
3. Use the kinetic theory of matter to explain why the liquid expanded when heated.

STATION 3: HEATING GASES

What you need

- Balloon
- 100 mL conical flask
- String
- Ruler
- 250 mL beaker of hot water
- Ice bath (250 mL beaker of water and ice)

What to do

1 Blow up the balloon to help stretch the rubber. Let the air out again until it is about the size of an apple.
2 Place the balloon over the neck of the flask.
3 Use the string and ruler to measure the circumference of the balloon at room temperature. Complete the following table and record this measurement.

Temperature	Balloon circumference (cm)
Room temperature	
Hot water	
Ice bath	

4 Place the flask with the balloon in a beaker of hot water. Wait a few minutes.
5 Measure and record the balloon's circumference.
6 Place the flask with the balloon in an ice bath with a small amount of water. Wait a few minutes, and then measure and record the balloon's circumference.

Results

Record your observations, including your table.

Discussion

1 What happened to the size of the balloon as the temperature went from cold to hot?
2 Was any air added to change the size of the balloon?
3 Use the ideas of the particle model of matter to explain how the balloon expanded and contracted with the changes in temperature.

Conclusion

What do you know about the effects of heat on solids, liquids and gases?

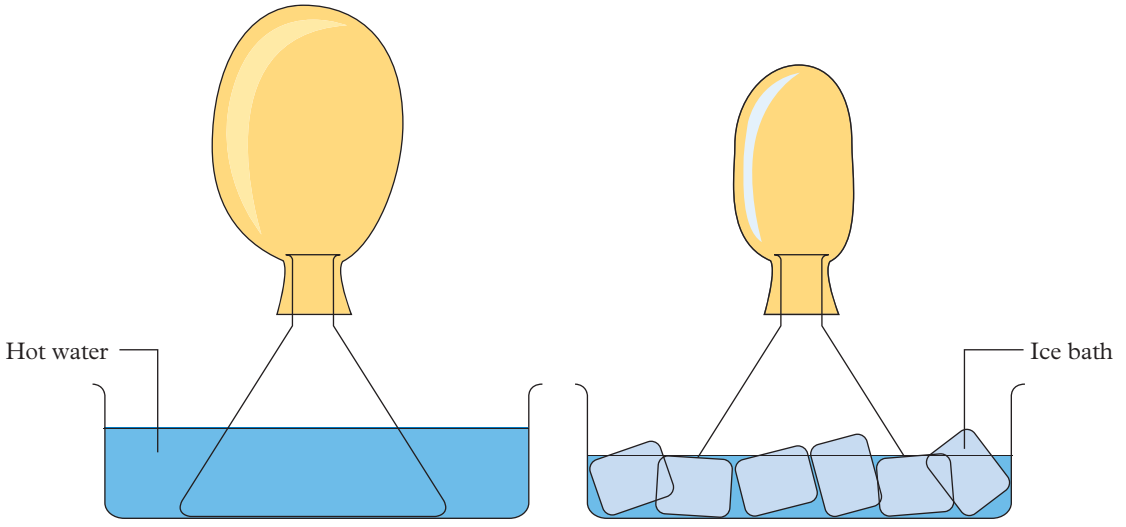


Figure 2 Experimental set-up to show the expansion and contraction of a gas after heating and cooling

15.6B From ice to steam

INVESTIGATION

Aim

To investigate the melting and boiling points of water.

Risk assessment
15.6B From ice to steam

Lab tech notes
15.6B From ice to steam

CAUTION! Steam and boiling water can both scald. Take great care when measuring the higher temperatures. If scalded, place the area of skin under cold running water for at least 5 minutes and show your teacher.

Wear safety glasses and lab coat, and tie long hair back, when using a Bunsen burner.

What you need

- 250 mL beaker
- Crushed ice
- Water
- Tripod stand
- Bunsen burner
- Heating mat
- Gauze mat
- Stirring rod
- Timer
- Retort stand
- Clamp
- Boss head
- Thermometer (0–110°C) or thermistor probe

What to do

1 Place some ice and water into the beaker.

2 Wait until most of the ice has melted.

3 While you are waiting, prepare a tripod stand, Bunsen burner, heating mat and other equipment so that you can heat the water in the beaker. Set up a clamp to hold a thermometer or a thermistor probe that is connected to a data logger.

4 Complete the following table.

Time (minutes)	Temperature (°C)
0	
1	
2	
3	
4	
5	

5 Place some crushed ice and a small amount of tap water in the beaker. Stir with the stirring rod for approximately 1 minute.

6 Measure and record the temperature of the water and ice mixture. This is the melting point of water. Record the temperature in your table at time 0.

7 Set up the equipment as shown in Figure 1, checking to make sure the thermometer is not touching the bottom of the beaker and that it is secure in the clamp. Do not stir with the thermometer.

8 Light the Bunsen burner and start heating the ice and water.

9 Measure and record the temperature of the mixture in the beaker every minute until the water starts to boil and produce steam. This is the boiling point of water.

10 Continue heating for another 4 minutes, unless most of the water has evaporated.

11 Using graph paper, or a suitable computer program, draw an appropriate graph with temperature on the vertical axis and time on the horizontal axis.

Results

Record your observations, including your table and graphs.

Discussion

1 a At what temperature did you measure the melting point of ice?

b How does your measured melting point of ice compare with the standard measurement of 0°C?

2 a At what temperature did you measure the boiling point of water?

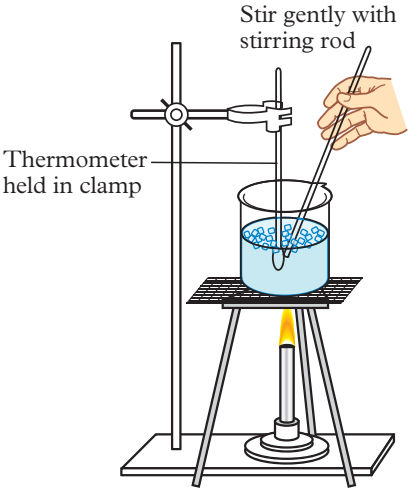


Figure 1 Experimental set-up for measuring the melting point of ice

b How does your measured boiling point of water compare with the standard measurement of 100°C?

3 Were there times when it was difficult to read the thermometer? Why?

4 Compare your results with those of the rest of the class. Suggest why there is a variation in the answers.

Conclusion

What do you know about the melting and boiling points of water?

16.2B Identifying the elements in the periodic table

CHALLENGE

Aim

To identify elements and their properties on the periodic table.

Risk assessment
16.2B Identifying the elements in the periodic table

Lab tech notes
16.2B Identifying the elements in the periodic table

What you need

- A copy of the periodic table
- Coloured pencils

What to do

1 On your periodic table:
   - Draw a triangle around all the elements that are liquids.
   - Draw a circle around all the gases.
   - Draw a square around all the metalloids.
   - Colour all the transition metals in blue.
2 Choose one element on the table.
   - Colour your element in green.
   - Colour the period that your element belongs to red.
   - Colour the group your element belongs to yellow.
3 Research the following information for your element:
   - List its name, symbol, atomic number and atomic mass.
   - List five properties for your element.
   - List some uses for your element.
   - List where your element can be found.
   - Who discovered your element?
4 Is your element dangerous? A Safety Data Sheet (SDS) is provided for every dangerous substance. It contains information about the risks involved in handling the substance. Research an SDS for your chosen element and record the following information:
   - risks associated with your element
   - how to handle your element safely.

16.2 Properties of the elements

INVESTIGATION

Aim

To compare the differences between different elements of the periodic table.

Risk assessment
16.2 Properties of the elements

Lab tech notes
16.2 Properties of the elements

What you need

- Steel wool
- Aluminium
- Copper
- Magnesium
- Graphite/lead pencil
- Zinc
- Iron nail (non-galvanised)
- Forceps
- Battery
- 3 wires
- Lamp
- 0.5 M hydrochloric acid
- Distilled water
- 6 test tubes
- Test tube holder

What to do

1 Use the steel wool to rub a small section of your material. Record the colour and appearance in the following table. Is it shiny or dull?

Element	Is it shiny or dull?	Is it malleable or brittle?	Does it conduct electricity?	Does it react with acid?

2 Use the forceps to try to bend each substance. Is it malleable (able to bend)? Is it brittle (breaks when bent)?
3 Set up a circuit with the battery, lamp and wires, as shown in Figure 1. Connect the two loose wires to the material. Does the light glow? Does your material conduct electricity?
4 Replace your sample into the test tube and add 3 cm of hydrochloric acid to the test tube. Do you see any immediate reaction? If possible, leave it overnight to see if there is any change.
5 Repeat your tests with all of your samples and record your observations in the table.

Results

Record your results in a table.

Discussion

1 What similarities do you observe between the elements you tested?
2 Can you divide all the materials into two groups? What properties do you use to separate the materials?
3 If you discovered a new material that was shiny and bent when you dropped it, which groups would you put it in? Explain. What other properties might you expect it to have?

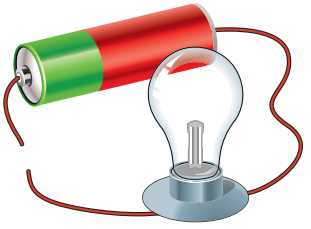


Figure 1 This incomplete circuit can measure the conductivity of objects.

Conclusion

Describe what you know about the physical and chemical properties of these materials.

16.5 Decomposing copper carbonate

INVESTIGATION

Aim

To decompose (break into smaller parts) copper carbonate.

Risk assessment
16.5 Decomposing copper carbonate

Lab tech notes
16.5 Decomposing copper carbonate

CAUTION! Wear safety glasses and lab coat, and tie long hair back, when using a Bunsen burner.
Use a yellow (cooler) safety flame for this experiment.
Hold the test tube or crucible securely with the tongs and always point it away from yourself and others.
Never place hot objects on the balance.

What you need

- Plastic beaker
- Test tube
- Electronic balance
- Spatula
- Copper carbonate
- Bunsen burner
- Heating mat
- Tripod stand
- Matches
- Wooden tongs
- Paper towel
- Timer

What to do

1 Place a plastic beaker containing the test tube on the balance. Tare the balance so that it reads zero.
2 Using a spatula, add approximately 3 g of copper carbonate into the test tube. Record the mass in grams (this is 'W1' in the results table).
3 Set the Bunsen burner up on the heating mat. Light the flame, ensuring the hole is closed and a yellow (safety) flame is burning.
4 Using the wooden tongs to hold the top of the test tube, gently wave the base of the test tube over the flame twice. Record any changes. Continue to do this for 2 minutes, recording any changes. Be very careful to point the open end of the test tube away from others and yourself.
5 Allow the test tube and copper carbonate to cool. Wipe any black powder from the outside of the tube off with paper towel.
6 Place the test tube in the original plastic beaker. Check that the balance is zero. Reweigh the test tube and beaker and record the mass in grams (this is 'W2'). Note any change in weight.

Results

Record your results in the following table.

Weight of copper carbonate before heating (W1) (g)	Weight of copper carbonate after heating (W2) (g)	Difference W1 – W2 (g)

Discussion

1 What happened to the copper carbonate? Consider the colour and any change in mass.
2 What evidence is there that copper carbonate is a compound and not an element?
3 What are the possible sources of error in this experiment?

Conclusion

What happens when copper carbonate decomposes?

17.1 Comparing different types of mixtures

CHALLENGE

Aim

To compare mixtures.

Risk assessment
17.1 Comparing different types of mixtures

Lab tech notes
17.1 Comparing different types of mixtures

PART A: DIRTY WATER

What you need

- Soil
- Water
- Jar with screw-top lid

What to do

1 Put some soil and water in the jar to create a watery mixture.
2 Screw the lid on tightly and then shake the jar.
   - What happens to the soil particles?
   - Does anything float on the water?
   - How can you explain the behaviour of this mixture?
   - What type of mixture is dirty water?

PART B: MAKING A FOAM

CAUTION! Check for egg or dairy allergies.

What you need

- Cream or egg white
- Hand or electric whisk
- Large metal bowl

What to do

1 Whip the cream or egg white until it increases significantly in size and holds its shape.
   - Explain why the foam you have created is classified as a colloid.

PART C: MIXING OLIVE OIL AND WATER

What you need

- Olive oil
- Water
- Jar with screw-top lid
- Detergent

What to do

1 Two-thirds fill a jar with equal parts of water and oil. Observe what happens.
2 Screw the lid on the jar tightly and shake the mixture vigorously. Observe what happens immediately and over time.
3 Add a couple of drops of detergent to the mixture and shake the jar again.
   - How does the mixture change when you add the detergent?
   - Explain what is happening using the terms 'colloid', 'mixture', 'emulsion' and 'emulsifier'.

PART D: ADDING SUGAR TO WATER

What you need

- Water
- Table sugar
- Teaspoon
- Beaker or glass

What to do

1 Add a small amount of sugar to water in a glass and stir.
   - Describe what has happened to the sugar.

PART E: MAKING PERFUME

CAUTION! Methylated spirits is a flammable liquid. Do not use near a flame.

What you need

- Lavender flowers
- Methylated spirits
- Scissors
- Jar with a lid
- cotton bud

What to do

1 Cut the lavender flowers into tiny pieces and place them in the jar.
2 Cover the lavender flowers with methylated spirits.
3 Seal the jar and leave overnight.
4 The following day, dip a cotton bud in the methylated spirits.
5 Allow the methylated spirits to evaporate and then smell.
   - Why is this mixture considered to be a solution? Identify the solute and the solvent.
   - Would this experiment work if you put the lavender flowers in a jar of water?
   - Why is it handy that the methylated spirits evaporate easily?

Discussion

1 Why is this mixture considered to be a solution? Identify the solute and the solvent.
2 Would this experiment work if you put the lavender flowers in a jar of water?
3 Why is it handy that the methylated spirits evaporate easily?

17.2 What if salt was dissolved in water?

INVESTIGATION

Aim

To investigate whether a mixture of salt and water forms a solution.

Risk assessment
17.2 What if salt was dissolved in water?

Lab tech notes
17.2 What if salt was dissolved in water?

What you need

- Test tubes
- Test tube rack
- Spatula
- Salt

What to do

1. Add 5 cm of water to a test tube.
2. Add 1 spatula of salt to the test tube. Carefully stir the mixture.
3. Does the mixture form a solution? Record your results.

Inquiry: What if other substances are mixed with water?

You could test powders such as copper carbonate, bath salts, talcum powder, brown sugar and flour.

- Which (independent variable) are you changing from the method above?
- Name three variables you will need to keep the same, as in the method above.
- How will you know if your new powder forms a solution with water?
- Predict which powders will form a solution.
- What equipment will you need to complete this investigation?
- Write down the method you will use to complete your investigation.
- What sort of table will you need to draw to show your results?

Show your teacher your planning for approval.



Figure 1 Adding salt to water

Results

Complete your investigation, filling in your table of results.

Discussion

1. How many substances were soluble in water? List them.
2. Of the substances that did not dissolve, did any form a suspension?
3. Which substances took the longest to dissolve? Why do you think this happened?
4. Were any of your results unexpected?
5. Name three other substances you know dissolve in water.
6. Do you think water is a good solvent? Give reasons based on the results of your investigation.
7. How would you change this investigation to find out more about dissolving substances?

17.3A Separating mixtures using sedimentation and flotation

SKILLS LAB

Aim

To separate mixtures using sedimentation and flotation.

Risk assessment
17.3A Separating mixtures using sedimentation and flotation

Lab tech notes
17.3A Separating mixtures using sedimentation and flotation

What you need

- Two mixtures: 'A' contains sand and sawdust, and 'B' contains sand and salt water
- Spatula
- Stirring rod
- Two beakers

What to do

1. Place at least three heaped spatulas of mixture A into a beaker.
2. Add water and stir the mixture.
3. Wait until sedimentation has occurred.
4. Scoop off any floating material from the top of the water. Decant the water to retrieve the sand.
5. Repeat the procedure for mixture B.
6. Draw a labelled diagram of your results.

Questions

1. How successful was the method for separating and collecting the sand from mixture A?
2. How successful was this method for collecting sand from mixture B?
3. What are some of the difficulties with decanting?
4. List the advantages of the combined sedimentation–flotation separation system.
5. After separating the two substances from mixture B, what would need to be done to collect the salt as a solid?

Clean-up

After separating a mixture, make sure that all insoluble solids go into a specially provided container. Only throw substances in the bin if your teacher says it is okay to do so. Never wash solids down the sink.

1. Think of three reasons why disposing solids down the sink is not a good idea.

17.3 What if a flocculent was added to muddy water?

INVESTIGATION

Aim

To investigate the effect of a flocculent.

Risk assessment
17.3 What if a flocculent was added to muddy water?

Lab tech notes
17.3 What if a flocculent was added to muddy water?

CAUTION! Handle the aluminium sulfate solution with care, wear eye protection and avoid contact with skin.

What you need

- Muddy water (3 g dirt in 50 mL water)
- 2 jars
- 0.5 M sodium carbonate solution
- 0.5 M aluminium sulfate solution

What to do

1. Half-fill each jar with muddy water and label one 'A' and the other 'B'.
2. Add half a test tube of aluminium sulfate solution to jar A.
3. Slowly add half a test tube of sodium carbonate solution to jar B.
4. Leave both jars undisturbed for approximately 15 minutes.
5. Record your observations, comparing the water in jar A with that in jar B.

Inquiry: How much flocculent is needed to effectively separate a mixture of mud and water?

- What amounts of the flocculent will you add to the muddy water mixture?
- How will you measure if the muddy water is separated enough? (Hint: How much light should shine through the mixture?)
- Name three variables you will keep the same, as in the first method.
- Write down the method you will use to complete your investigation.
- What sort of table will you need to draw up to show your results?

Show your teacher your planning for approval.

Results

Complete your investigation, filling in your table of results.

Discussion

1. What effect did the aluminium sulfate solution have on the muddy water?
2. What effect did the sodium carbonate solution have on the muddy water?
3. Which of the two substances – aluminium sulfate or sodium carbonate – acted as a flocculent? Give evidence to support your answer.
4. Why might it be important for water treatment plants to minimise the amount of flocculent added to wastewater?

Conclusion

What effect does a flocculent have on mixtures?

17.3B Separating using magnetic properties

SKILLS LAB

Aim

To separate a mixture using a magnet.

Risk assessment
17.3B Separating using magnetic properties

Lab tech notes
17.3B Separating using magnetic properties

What you need

- Mixture of iron filings and sand
- Magnet
- Plastic bag

What to do

1. Place the magnet inside the plastic bag.
2. Pass the bagged magnet over the mixture so that the iron filings are attracted.
3. Turn the plastic bag inside out so that all the iron filings are trapped.

Questions

1. How effective do you think this method was at separating the iron filings from the sand?
2. Could you use this method for all metals? Explain.

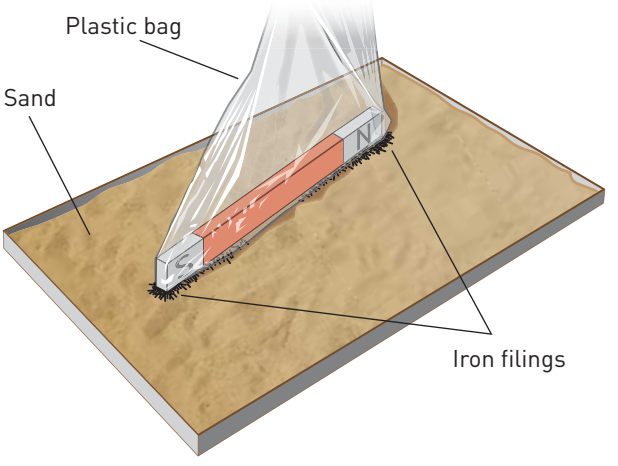


Figure 1 Experimental set-up

17.4 Filtering a mixture of sand and water

SKILLS LAB

Aim

To filter a mixture.

Risk assessment
17.4Filtering a mixture of sand and water

Lab tech notes
17.4Filtering a mixture of sand and water

What you need

- Mixture of sand and salt
- Beaker
- 100 mL conical flask
- Spatula
- Small funnel
- Filter paper
- Stirring rod

What to do

1 Fold a round filter paper in half, then in half again to get quarters and finally in half again to get eighths, as shown in Figure 1.
2 Unfold the filter paper and lay it flat (see Figure 2).
3 Re-fold back and forth over the creases in the filter paper to obtain a fluted shape, as shown in Figure 3.
4 Set up the funnel and flask, as shown in Figure 4.
5 Place the filter paper into the funnel, as shown in Figure 5.
6 Dampen the filter paper with some extra water to help it stick to the sides of the funnel (see Figure 6).
7 Swirl the sand mixture and slowly pour it from the beaker into the funnel (Figure 7). Do not overfill the funnel.
8 Keep adding the mixture slowly until it is all used up.
9 Extra water can be added to the beaker mixture to pour out the last solid particles.
10 Wait for the filtering to finish. Remove the filter paper carefully and allow it to dry. In most experiments, the residue (the solid on the paper) is kept and the filtrate (the liquid in the flask) is discarded.

Questions

1 Draw a scientific diagram of your equipment. Label the filtrate and residue.
2 What physical properties are being used to filter substances?
3 Describe at least three things you need to be careful about when filtering.



Figure 1 Folding filter paper in half



Figure 2 Unfolding the filter paper and laying it flat



Figure 3 Re-folding the filter paper



Figure 4 Setting up the funnel and flask



Figure 5 Placing the filter paper in the funnel



Figure 6 Dampening the filter paper with extra water



Figure 7 Pouring the sand mixture into the funnel

17.5 Crystallisation of salt water

INVESTIGATION

Aim

To separate a salt from a solution by evaporation and crystallisation.

Risk assessment
17.5 Crystallisation of salt water

Lab tech notes
17.5 Crystallisation of salt water

What you need

- Evaporating dish
- Tripod
- Clay triangle
- Bunsen burner
- Heatproof mat
- Salt solution
- 250 mL beaker
- Magnifying glass
- Matches

What to do

1. Collect a sample of the salt solution.
2. Half-fill an evaporating dish with the solution.
3. Place the evaporating dish on the clay triangle over the tripod.
4. Heat the evaporating dish, with the flame at full strength.
5. When the solution starts boiling, half-close the Bunsen burner collar. (Don't change to a yellow flame – this is not the same.)
6. Add more solution to the dish as the level drops due to evaporation. Be careful as the evaporation nears completion because the hot salt may spit and splatter.
7. Turn off the Bunsen burner when just a little liquid remains with the salt. Leave the dish to cool.
8. Examine the salt crystals with a magnifying glass.

Results

Draw a diagram of the crystals in your notebook.

Discussion

After the water has evaporated from the solution, salt remains in the evaporating dish.

1. If the solution contained a mixture of more than one solute, would the separation technique used in this investigation be suitable? Explain.
2. What is wasted in this experiment? Can you think of any way this could be avoided?

Conclusion

Explain how evaporation and crystallisation can be used to separate a mixture of salt and water.

17.5 Designing a way to purify water from sea water

CHALLENGE

Design brief

You are preparing for a natural disaster that will affect the water supply. Design some equipment that will enable you to provide drinking water for a single person from sea water indefinitely.

Risk assessment
17.5 Designing a way to purify water from sea water

Lab tech notes
17.5 Designing a way to purify water from sea water

Criteria restrictions

- Your materials must be available in a supermarket or your home.
- You must provide the cost of building your equipment.
- Your only available heat source is the Sun.

Questioning and predicting

- How will you heat the water so that it evaporates?
- How will you collect the steam?
- How will you cool the steam so that it condenses?
- Draw a labelled diagram of your design.
- Build a prototype of your design.

Processing and analysing

1. What changes did you have make to improve your design?
2. What was the most successful feature of your design? What was the least successful?
3. What was the final cost of your design?
4. Is there any practical use for your design?
5. If you were doing this experiment again, how would you modify your design? Explain.

Communicating

Present the various stages of your investigation in a formal experimental report.

17.6A Who wrote the nasty note?

CHALLENGE

Your forensic laboratory is investigating a crime of extortion: one person is forcing or frightening another into handing over money.

The police have identified that the extortion note was written with a black felt-tip pen. They have collected a black felt-tip pen from the three suspects: Aunt Aggie (A), Cousin Cranky (C) and Uncle Buncle (U).

Other forensic scientists in your laboratory have already run a chromatography test on the note written by the extortionist. After you have tested the three pens from the suspects, collect the chromatogram from the original note from your teacher for comparison.

Risk assessment
17.6A Who wrote the nasty note?

Lab tech notes
17.6A Who wrote the nasty note?



Figure 1 The suspects

Aim

To separate the inks from three different water-soluble black felt-tip pens.

What you need

- 3 black water-soluble felt-tip pens (they must all be different brands and labelled 'A', 'C' and 'U') (Note: Permanent markers are not suitable for this experiment because they are not water-soluble.)
- 250 mL beaker
- Glass rod
- Salt solution (1%)
- Filter or chromatography paper
- Scissors
- Pencil
- Ruler

What to do

1. Cut the filter or chromatography paper into three strips measuring approximately 2 cm × 10 cm.
2. Draw a faint pencil line across the width of each paper strip, 3 cm from the bottom.
3. Label one strip 'A', another 'C' and the remaining one 'U'. Make sure the label is at the very top of the paper strip.
4. Carefully trace over the pencil line at the bottom of strip A with the first felt-tip pen. (Do not make the line too thick.)
5. Do the same for the other two pens on their separate strips.
6. Add the salt solution to the bottom of the beaker, no deeper than approximately 2 cm.
7. Hang the paper strips over the glass rod so that they just dip into the salt solution. Make sure the salt solution does not touch the pen lines on the paper.
8. Leave the papers to soak up the salt solution for approximately 10–15 minutes, or until the solvent level is up to the top of the paper.
9. In the meantime, draw a diagram of the chromatography equipment in your notebook, labelling all the parts.
10. When the chromatogram is finished, take the papers out of the solution to dry.

Results

Tape the dry chromatograms for suspects A, C and U in your notebook or workbook. Collect and copy the chromatogram from the original note. Label this as the extortionist's chromatogram.

Discussion

1. Compare the chromatogram for the extortionist with the chromatograms from the three suspects. Do any of the suspects' chromatograms match the one from the original note? If so, who is most likely to be guilty?
2. Which felt-tip pen – A, C or U – had the most colours in its black ink?

Conclusion

How can the inks from three different black felt-tip pens be separated?



Figure 2 Tracing over the pencil lines at the bottom of the chromatography paper



Figure 3 Hanging the paper strips over a glass rod so that they just dip into the salt solution

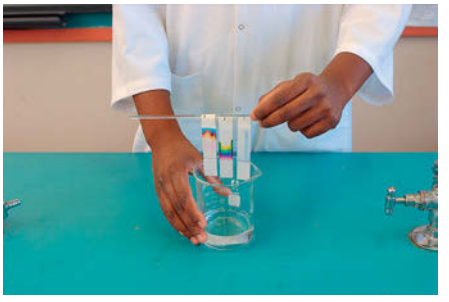


Figure 4 Taking the papers out to dry

17.6B Separation challenge

CHALLENGE

Challenge

Now that you are a scientist who has trained in separating techniques, it is time to separate a mixture of sand, salt, sawdust and iron filings.

Risk assessment
17.6B Separation challenge

Lab tech notes
17.6B Separation challenge

Criteria restrictions

You may only use equipment available in the laboratory.

Questioning and predicting

1 Think about the properties of each pure substance. This may help you decide on a way to separate the substances. Fill in what you know about the properties of sand, iron filings, sawdust and salt into the table below.

Substance	Soluble in water?	Attracted to a magnet?	Floats/sinks in water?
Sand			
Iron filings			
Sawdust			
Salt			

2 Discuss with a partner some possible ways to separate the four substances.

Planning and conducting

- Draw up a flow chart showing the steps you will take to separate the four substances.
- Devise an aim and an equipment list for your challenge.
- Write a detailed method for separating the substances. Include at least two diagrams.
- What safety issues might there be when doing this challenge?
- Have your plan checked by your teacher.
- Perform your separations and make relevant observations.

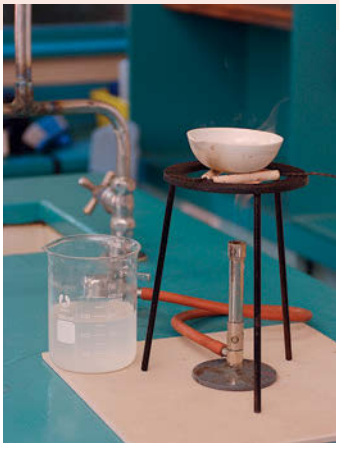


Figure 1 Some of the equipment you may need for the separation challenge

Processing and analysing

1 How well did your plan work? Grade the success of the plan on a scale of 1–5, where 1 means the challenge did not work well and 5 means it was a great success. If you completed this challenge as a group, discuss your grading with others in your team.

2 If your success was lower than 5 on the scale, how would you change 'plan B' to improve the results on another occasion?

3 Did you manage to separate the four substances successfully? Write your answer to this question as the conclusion in your laboratory report.

Communicating

Present the challenge in a formal experimental report.

18.1 Exploring physical changes

CHALLENGE

Aim

To make physical changes to substances.

Risk assessment
18.1 Exploring physical changes

Lab tech notes
18.1 Exploring physical changes

What you need

- Aluminium drink can
- Elastic/rubber band
- Rock salt
- Ice
- Sugar cube
- Vitamin C tablet
- Slice of bread
- Piece of cloth
- Scissors

What to do

1 For each of the materials provided, find ways to change their physical appearance.

2 Record the methods used and observations in the following table.

Material	Method used	Has the substance changed?	Can the change be reversed/undone?

Discussion

1 List three different ways a physical change can take place.

2 What did each change have in common?

18.2 Observing chemical reactions

INVESTIGATION

Aim

To observe the reactants and products in chemical reactions.

Risk assessment
18.2 Observing chemical reactions

Lab tech notes
18.2 Observing chemical reactions

What you need

- Spatula
- Copper carbonate (solid)
- Bunsen burner
- Heating mat
- Matches
- 2 test tubes
- Test tube holder
- Baking soda (sodium bicarbonate)
- 1 M hydrochloric acid (5 mL)
- Thermometer
- Wooden splint
- Magnesium ribbon (1 cm length)
- ~0.5 M copper sulfate solution
- 100 mL beaker
- Tongs
- Piece of iron wool, about thumb size when rolled up

What to do

Part A

1 Place a large spatula of copper carbonate in a test tube.
2 Set up the Bunsen burner.
3 Using a test tube holder, gently heat the test tube by passing it over the flame twice. Make sure the test tube is facing away from you and anyone else. Observe any changes and repeat until the powder changes colour.
4 Collect the waste powder in a beaker for disposal.

Part B

1 Place the baking soda in a test tube to a depth of 0.5 cm.
2 Add an equal amount of 1 M hydrochloric acid to the test tube and observe.
3 Conduct a carbon dioxide test by holding a burning wood splint above the tube. If the flame goes out, carbon dioxide is present as one of the products of the chemical reaction.

Part C

1 Pour 5 mL of hydrochloric acid into the bottom of a test tube. Measure its temperature with the thermometer.
2 Add the magnesium ribbon to the test tube. Measure its temperature again.
3 Observe what happens using sight, touch (the outside of the tube only!) and sound.

Part D

1 Pour approximately 30 mL of the copper sulfate solution into a 100 mL beaker.
2 Use the tongs to place the steel wool into the copper sulfate solution.
3 Carefully observe the changes that occur to both the iron wool and the copper sulfate solution.
4 Collect the copper sulfate–steel wool solution in a beaker for safe disposal.

Results

Include your observations here.

Discussion

1 What happened to the copper carbonate when it was heated?
2 Did it change when taken away from the heat?
3 What is produced in the baking soda and acid experiment?
4 Why does the flame on the burning splint go out if carbon dioxide is present?
5 What happened to the magnesium metal?

Conclusion

What did you observe about the reactants and products of chemical reactions?



Figure 1 When heating a test tube, be sure to point it away from you or anyone else close by.

18.3 Comparing reactants and products

INVESTIGATION

Aim

To examine the physical and chemical properties of reactants and products.

Risk assessment
18.3 Comparing reactants and products

Lab tech notes
18.3 Comparing reactants and products

CAUTION! Hydrochloric acid may cause chemical burns. Wear safety glasses, lab coat and gloves.

What you need

- Piece of magnesium ribbon (1 cm)
- 1 pea-sized sample of magnesium oxide powder
- 20 mL of 1 M hydrochloric acid
- 2 test tubes
- Test tube rack
- Marker pen

What to do

1. Place 2 test tubes in a test tube rack. Label one test tube Mg (magnesium) and the other MgO (magnesium oxide)
2. Examine each sample by looking and carefully moving the sample in the bottom of the test tube. Record your observations in your table.
3. Add 10 mL of 1 M hydrochloric acid into each test tube in the test tube rack.
4. Observe any reactions. Record your observations in the following table.

Substance	Colour	State	Shiny/Dull	Reaction with acid
Magnesium				
Magnesium oxide				

Results

Write a short statement describing each sample.

Discussion

1. Do magnesium and magnesium oxide have the same physical properties?
2. Do magnesium and magnesium oxide have the same chemical properties?

Conclusion

What do you know about the physical and chemical properties of reactants and products?



Figure 1 This experiment requires magnesium ribbon.

18.4 Making casein glue

INVESTIGATION

Casein is a protein in milk. It can be extracted from milk and chemically changed so that it has the properties of a glue.

Risk assessment
18.4 Making casein glue

Lab tech notes
18.4 Making casein glue

Aim

To improve the manufacture of casein glue.

CAUTION! Ammonia has a strong odour and can cause chemical burns. Use in a fume cupboard under teacher supervision. Wear safety glasses, lab coat and gloves.

What you need

- Full cream milk (70 mL for each group of students)
- 250 mL beaker
- Bunsen burner
- Heating mat
- Tripod stand
- Gauze mat
- Matches
- Thermometer
- Heatproof glove
- Vinegar (20 mL)
- Stirring rod
- Sieve
- Disposable cleaning cloth
- Ammonia solution (2 drops) (teacher use only)
- Icy pole sticks (for gluing together)

What to do

1. Pour 70 mL of milk into the 250 mL beaker.
2. Set up your Bunsen burner and heat the milk to ***no more than 50°C***. Remove the milk from the heat using a heatproof glove.
3. Slowly add 20 mL of vinegar to the milk, with gentle stirring. Do not stir vigorously as you will break up the curd (lumpy bits) being formed. The curd should clump as much as possible.
4. Set up the sieve over the sink or a large beaker. Put a piece of disposable cloth over the sieve.
5. Gently pour the mixture through the cloth and sieve to filter the whey (liquid) from the curds (lumps of mainly protein). Once it has stopped dripping, very gently squeeze the cloth to remove any excess liquid.
6. Return the solids to the original 250 mL beaker and carry it to the fume cupboard for your teacher to add two drops of ammonia.
7. While your sample is in the fume cupboard, stir it well.
8. Take your sample and two icy pole sticks to your bench.
9. Spread your sample between the sticks and press them together. Leave them overnight and then test how well your glue has worked.

Inquiry: Choose one of the questions below to investigate

- What if skim milk was used?
- What if soy milk was used?
- What if more vinegar was used?
- What if no ammonia was added?

Answer the following questions in relation to your inquiry:

- Write a hypothesis for your question.
- Which (independent) variable will you change from the first method?
- How will you determine which glue is stronger?
- Name three variables you will keep the same/control.

Results

Record your observations and measurements in a table.

Discussion

1. Why is it important to wear safety glasses in this experiment?
2. What are the reactants used in this experiment? What are the products?
3. How could you compare the strengths of different glues?
4. How do you think someone worked out that you could make glue from milk?

Conclusion

What do you know about making glue?



Figure 1 This experiment requires full cream milk.

GLOSSARY

A

abiotic
all the non-living components of an ecosystem; for example, light, temperature and water

accuracy
careful, correct and consistent measurement or processing of data

adaptation
a characteristic or feature of an organism that assists in its survival and reproductive success

adenosine triphosphate (ATP)
a compound that is used as the source of energy for cellular activities

agriculture
the large-scale cultivation of animals and crops

aim
the purpose of an experiment

air resistance
friction between a moving object and the air it is moving through

algal bloom
the rapid growth of algae in water

alkali metal
an atom found in group 1 of the periodic table

alkaline earth metal
an atom found in group 2 of the periodic table

alveoli
tiny air sacs in the lungs where gas exchange occurs

amino acid
a small molecule that makes up a protein

ammonia
a toxic substance produced by the liver, a cleaning fluid

amoeba
a type of single-celled organism belonging to the Protista kingdom

animal husbandry
the science of breeding and caring for farm animals

apoptosis
programmed cell death

apparatus
equipment placed together for an experiment

aqueous solution
a solution in which the solvent is water

arterioles
smaller arteries

artery
the thick muscular-walled blood vessel that carries blood away from the heart under pressure

artificial insemination
the introduction of sperm from a male with desirable traits into a female

artificial organ
a device or tissue developed to replicate the function of a real organ

asthma
a respiratory condition that causes the airways to narrow or produce extra mucus

astronomer
a scientist who studies celestial bodies

atmosphere
layer of gases that surround Earth and other planets

atom
smallest particle of matter that cannot be created or destroyed

atomic number
the number of protons of an atom

attraction force
the force that attracts one object to another

autotroph
an organism that makes its own 'food', such as glucose, through photosynthesis

axis
an imaginary straight line joining the north and south poles of the Earth

B

bacteria
unicellular organisms with a cell wall but no nucleus

balanced forces
two forces equal in size and opposite in direction

binary fission
a form of asexual reproduction used by bacteria; the splitting of a parent cell into two equal daughter cells

binomial name
a double-name system created by Linnaeus to name organisms; the first name is the genus and the second name is the species

biofuel
a fuel produced from biomass

biomass
plant or animal material we use from the biosphere to produce energy

biopolymer
a polymer developed from living things

biosphere
the regions of the lithosphere, hydrosphere and atmosphere inhabited by living organisms

biotic
all the living organisms in an ecosystem

blood
the liquid that circulates in the blood vessels and contains a combination of cells, cell fragments, liquid and dissolved substances

blood vessel
a tube in the body that carries blood

boil
to change state from a liquid to a gas

boiling point
the temperature at which a liquid boils and turns to a gas

botanist
a scientist who studies plants

branched key
a method of identifying a species using questions that lead to further questions and eventually to the identification of the species

bronchi
the air passages that carry air in and out of the lungs; airways

budding
the process where a single bud of the desired plant is inserted into a slit in the bark of a compatible root stock

Bunsen burner
used as a heat source in the laboratory

by-product
a secondary, sometimes unintended, product from a process

C

calibrate
to check the accuracy of a meter against known measurements

cancer
a group of diseases that result from uncontrolled cell division

capillary
a blood vessel with a wall only one-cell thick, allowing for substances to easily pass into and out of the blood

carcinogen
a cancer-causing substance

carcinogenic
(a substance that) has the potential to cause cancer

carnivore
an animal that eats only meat

cartilage
firm, flexible connective tissue that reduces the friction between joint bones

cell
(in biology) the building block of living things

cell membrane
the barrier around a cell that controls the entry and exit of substances into and out of a cell

cell theory
the theory that all organisms are composed of one or more cells; cells are the basic unit of life, and new cells are created from existing cells

cell wall
a structure that provides support around some cells

cellular respiration
the chemical process where sugars (glucose) and oxygen are converted into carbon dioxide, water and energy

centrifuging
a separation technique used to separate light particles from heavy particles by rapidly spinning the mixture in a container (called a centrifuge)

chemical digestion
the chemical breakdown of food into simpler substances that can be absorbed into the blood

chemical engineer
an engineer who combines existing materials and develops new materials

chemical potential energy
energy stored in chemicals, e.g. in food, fuel or explosives; also known simply as chemical energy

chemical property
how a substance behaves in a chemical reaction, e.g. how it reacts with acid

chemical reaction
where one or more substances (reactants) are transformed into different substances (products)

chemistry
a branch of science that deals with matter and changes that take place within it

chlorophyll
the green pigment found inside chloroplasts that absorbs solar energy and uses it in photosynthesis

chloroplast
an organelle found in plant cells that transforms solar energy into chemical energy

chromatography
a separation technique used to separate substances according to differing absorption to a surface (e.g. coloured dyes that make up pen ink)

chromosome
DNA molecule that carries genetic information

circuit diagram
a diagrammatic way to represent an electrical circuit

civil engineer
an engineer who plans and designs structures

class
a level of taxonomic classification below phylum and above order

cleavage
a number of smooth planes that a mineral breaks along

climate change
change in global climate patterns, including temperature, over time

cloning
the process of producing a genetically identical copy of an organism

coal
a fossil fuel formed from the remains of trees and plants that grew about 300 million years ago

colloid
a type of mixture that always looks cloudy because clumps of insoluble particles remain suspended throughout it – they don't settle as sediment

column graph
a graph in which the height of the columns represents the number measured

commensalism
relationship between two organisms from different species, in which one organism benefits and the other organism is not affected

community
different populations living in the same place at the same time

comparative dating
determining the age of rocks by comparing them with rocks of known age

compound light microscope
a microscope with two or more lenses

compressibility
the ability of a substance to be compressed (squashed); gases can be compressed but solids and liquids cannot

compressional strength
the capacity to withstand compression

concentrated
containing a large number of particles in the volume of solution

concentration
how much solute is dissolved in a solvent

conclusion
a statement that 'answers' the aim of an experiment; should be clear and reasoned and relate very closely to the aim

condensation
the change of state from a gas to a liquid; occurs when a gas cools down

conduction
the transfer of thermal energy (kinetic energy of particles) through direct contact; the atoms do not change their position in the material

conductor
a substance that allows the movement of thermal or electrical energy

consumer
an animal that cannot convert the Sun's energy into sugars and must eat to get the energy they need to survive

contact force
a force that occurs when two objects are touching each other

continuous data
data where the numbers can be any value

convection
the transfer of thermal energy by the movement of molecules in air or liquid from one place to another

convection current
the current or flow of air or liquid that results from the transfer of thermal energy through convection

cross-pollination
the exchange of pollen and ova between different plants of the same species

crust
the outer layer of the Earth

crystal
a small, organised particle in rocks that has smooth sides and sharp edges

crystallisation
a separation technique used in conjunction with evaporation to remove a dissolved solid from a liquid; after the liquid has been evaporated the solid remains, often in the form of small crystals

cutting
the process where segments of a plant, usually the stem, are cut and inserted into water or a growth medium

cytoplasm
the 'jelly-like' fluid inside the cell membrane that contains dissolved nutrients, waste products and organelles

D

daughter cell
a cell that results from parent cell division

decanting
a separation technique used to separate a sediment from the liquid it is in by carefully pouring the liquid away

decomposer
an organism, such as bacteria, that breaks down on dead organisms

density
the number of particles (mass) in a volume

dependent variable
a variable that may change as a result of the experiment

deposition
the laying down of sediment

desalination plant
a large facility set up to produce fresh water from salt water

desertification
the process by which fertile land becomes desert as a result of drought, deforestation or inappropriate agriculture

detritivore
an organism that obtains nutrients by consuming detritus (decomposing plant and animal parts)

diaphragm
the dome-shaped muscle that is attached to ribs and moves up and down beneath the lungs

dichotomous key
a diagram used in classification; each 'arm' of the key contains two choices

diffusion
the spontaneous spreading out of a substance through a liquid or gas, e.g. the diffusion of perfume in air

digestion
the process by which food is broken down and absorbed into the blood for transport to the cells

dilute
containing a small number of particles in the volume of solution

diploid
(of a cell or nucleus) having a set of paired chromosomes ($2n$)

discrete data
data where the numbers can only be whole numbers

discussion
a summary of findings, analysis of the design of an experiment; it includes any problems encountered and suggestions for improvement

dissolved
when a solute forms a solution

distillation
a separation technique that uses evaporation and condensation to separate a solid contaminant and the solvent in which it has dissolved (e.g. to get pure water from salt water)

DNA
a molecule that contains all the instructions for every job performed by the cell; this information can be passed from one generation to the next

domain
a very small section of a magnet

drag
see air resistance

drought
a prolonged period of abnormally low rainfall

dry cell
an object, such as a torch battery, that uses a chemical reaction to produce electrical energy

E

ecosystem
a number of communities together with the surrounding non-living factors

ectotherm
an organism with a body temperature that changes with the environment

efficient energy
the measure of the amount of useful energy transformed in an energy transformation process; usually expressed as a percentage of the input energy

elastic potential energy
the energy stored and processed by stretching or compressing an object, e.g. a stretched rubber band

electric charge
a positive or negative charge that is the property of subatomic particles that results in electrical energy

electric circuit
a closed pathway that conducts electrons in the form of electrical energy

electric current
the flow of electrical charge through a circuit

electric field
the area around an electrically charged object that can act on another object

electrical conductor
a material through which charged particles are able to move

electrical energy
energy associated with electric charge, either stationary (static) or moving (current)

electrical engineer
an engineer who designs and organises electric circuits and equipment

electrical insulator
a material that does not allow the movement of charged particles

electricity
the transfer of electrical energy by flow of electric charges

electromagnet
a magnet that uses electricity to create a magnetic field

electromagnetic radiation
a form of energy that can be released into space by stars, including visible light, infrared radiation (radiant thermal energy), X-rays and gamma rays

electron
a particle in an atom with a negative charge

electron microscope
a microscope that uses electrons (tiny negatively charged particles) to create images

electrostatic discharge
the sudden transfer of electrostatic charge between two objects

electrostatic force
a force between two objects caused by a build-up of negative charges

element
a pure substance made of only one type of atom

emission
the production and release of something (e.g. gas)

emphysema
a respiratory condition caused by damage to the alveoli

emulsifier
a substance that enables oil and water to form an emulsion

emulsion
a colloid of two or more liquids

endoskeleton
an internal skeleton

endotherm
an organism with a constant body temperature

energy efficiency
the measure of the amount of useful energy transformed in an energy transformation process; usually expressed as a percentage of the input energy

energy resource
a resource that can be used for the production of energy

energy transformation
conversion of energy from one type into another (e.g. in a toaster, the main energy transformation is from electrical to heat)

enzyme
a group of proteins that help to speed up chemical reactions

equinox
the day on which day and night are the same length

equipment
items used in the laboratory to conduct experiments

erosion
the movement of sediment to another area

error
the unavoidable and random inconsistency in measurement

ethanol
a type of alcohol that can be used for fuel

eukaryotic cell
a complex cell that contains a nucleus and membrane-bound organelles

evergreen
plants that do not lose their leaves

evaporate
to change in state from liquid to gas; also a separation technique used to separate dissolved solids from water

excretion
the process of removing wastes from bodies

exoskeleton
an external skeleton

experiment
an investigation used to solve a problem or find an answer to a question

extrusive igneous rock
rock formed at the Earth's surface by quickly cooling lava

eyepiece
lens where the eye is placed when using a microscope

F

fair test
a controlled experiment

fertilisation
stage of sexual reproduction involving the joining of gametes

field
the area in which a non-contact force can act on an object

filter paper
a paper sieve with tiny holes that are too small to see; solutions can flow through but most solid particles will not

filtering
a separation technique used to separate solids from liquids or solutions, depending on the size of the holes in the filter paper

filter paper
a paper sieve with tiny holes that are too small to see; solutions can flow through but most solid particles will not

filtrate
the substance that passes through a filter

flocculant
a chemical added to a mixture to make suspended particles clump together

foetus
the unborn offspring of an animal that develops from an embryo

foliation
layering in metamorphic rocks produced under uneven, high pressure

food chain
a diagram that shows who eats who in an ecosystem and how nutrients and energy are passed on

food web
several intertwined food chains, showing the extended relationships between different organisms

force
a push or pull that, if unbalanced, can cause a change in an object's motion

fossil
the remains (or imprint) of an animal or plant preserved in rock

fossil fuel
a non-renewable energy source formed from plant and animal matter

friction
the force that acts to oppose the motion between two surfaces as they move over each other

frost shattering
the process of weathering in which repeated freezing and melting of water expands cracks in rocks so that eventually part of the rock splits off

fume
when a substance evaporates to become a gas at room temperature

fungi
the organisms in this kingdom include mushrooms, yeasts, molds and mildews

G

gamete
a sex cell; in humans it is the egg and sperm

generator
a machine that converts the energy from the movement from a turbine, for example, into electrical energy

genus
a group of closely related species

geocentric model
a model of the universe that places Earth at the centre of everything

geologist
a scientist who studies rocks

geothermal energy
energy that comes from heat beneath the Earth's surface

germ theory
the theory that diseases are caused by microbes called germs

gestation
the length of time between fertilisation and birth

grafting
the process where a number of buds, shoots or twigs are placed on the stock plant

grain
a small rock particle; grain size can be used to identify rock type

gravitational field
the area around a body in which another body experiences a force of attraction

gravitational potential energy
energy stored due to the height of an object, e.g. a child at the top of a slide

gravity
a force of attraction that objects have on one another due to their masses

greenhouse gas
a gas (carbon dioxide, water, methane) in the atmosphere that can absorb heat

groundwater
water found beneath the Earth's surface

group
a vertical list of elements found in the periodic table that have characteristics in common

H

habitat
an environment in which an organism lives

haemoglobin
a chemical found in red blood cells that transports oxygen around the body

haploid
(of a cell or nucleus) having a single set of unpaired chromosomes (*n*)

hardness
how easily a mineral can be scratched; measured on the Mohs hardness scale

herbivore
an animal that eats only plants

heterotroph
an organism that consumes other organisms to obtain energy

horticulture
a branch of agriculture that typically focuses on small garden crops, particularly fruits, vegetables and ornamental plants

humus
decomposed plants and animals

hybrid
a car that uses a mix of petrol and electricity

hydroelectric energy
energy produced by falling water that turns turbines to generate electricity

hydrosphere
the total amount of water on a planet

hypothesis
an initial prediction about the outcome of an experiment

I

igneous rock
rock formed by cooling magma and lava

incompressible
when a substance cannot be compressed; solids and liquids are incompressible

independent variable
a variable that is deliberately changed in an experiment

index fossil
a fossil found in different rocks that can be used to determine the age of rocks

index mineral
a mineral that only forms under a particular temperature and pressure; used to determine the history of the mineral

infectious disease
a disease caused by the passing of a pathogen from one organism to another; also known as contagious disease

inference
a likely explanation of an observation

insoluble
does not dissolve

insulator
a substance that prevents the movement of thermal or electrical energy

intrusive igneous rock
rock formed underground by slowly cooling magma

invertebrate
an organism with an exoskeleton (external skeleton) or no skeleton at all

K

key
a visual tool used in the classification of organisms

kinetic energy
the energy possessed by moving objects

kingdom
a taxonomic rank that is composed of smaller groups called phyla (historically kingdoms were the highest taxonomic rank; now superseded by domains)

L

laboratory
a specially designed space for conducting research and experiments

land degradation
the process of using up or removing the resources of land (e.g. water, topsoil, plants)

landform
a physical feature of the Earth's surface

lattice
three-dimensional arrangement of particles in a regular pattern

lava
hot, molten rock that comes to the surface of the Earth in a volcanic eruption

law of conservation of energy
the scientific rule that states that the total energy in a system is always constant and cannot be created or destroyed

layer
the property of rocks used to identify them

layering
the process where part of the stem is exposed to soil or moisture-holding materials, such as sphagnum moss, to achieve the best root development

leap year
a year that is 366 days long, occurring every four years

ligament
a type of connective tissue that connects bones to other bones

light energy
a form of energy, or electromagnetic radiation, that is visible

like poles
two north poles or two south poles of a magnet

line of best fit
the line on a scatter graph that passes through or as near to as many data points as possible

Linnaean taxonomy
a system of classification first developed by Carolus Linnaeus (1707–78), in which all organisms are grouped into one of five kingdoms

lithosphere
the rocky outer layer of the Earth's surface that is made up of the crust and uppermost part of the mantle

logbook
a record of the details of the work carried out in a science laboratory

low-emissions vehicle
a car or bus that releases very little exhaust gases, including carbon dioxide

lubrication
using a lubricant, such as oil or grease, to decrease friction

lunar eclipse
when the Earth moves between the Moon and the Sun

lustre
shininess

M

magma
hot, molten, semi-liquid rock beneath the Earth's surface

magnetic field
a three-dimensional space around an object where a magnetic force is experienced

magnetic poles
north and south ends of a magnet

magnetic
able to be magnetised or attracted by a magnet

magnetometer
an instrument that measures magnetism

marsupial
a mammal that gives birth to young that continue to develop in their mother's pouch

mantle
the part of the Earth between the crust and the outer core

mass
how many particles or atoms make up an object; the mass of an object does not change

matter
anything that has mass and volume

mechanical engineer
an engineer who deals designs and improves machines

meiosis
a type of cell division that produces specialised sex cells

melt
to change state from a solid to a liquid

melting point
the temperature at which a solid changes to a liquid

menstruation
the cycle involving the release of the egg and preparation of the uterus for pregnancy

metabolism
chemical reactions that occur in the body

metal
a collection of elements found on the left-hand side of the periodic table that are malleable, lustrous, ductile and highly conducting

metalloid
a small collection of elements that have a mixture of characteristics of metals and non-metals

metamorphic rock
rock formed from other rock that has experienced intense heat and pressure

meteorologist
a scientist who studies weather and climate

method
a list of how to do an experiment

metric system
a system of measurement

microbe
a living thing that can only be seen with the use of a microscope; a micro-organism

microbiologist
a scientist who studies micro-organisms

microbiology
the science involving the study of microscopic organisms

micro-organism
a microscopic organism; a microbe

microscope
a scientific instrument used to magnify the size of an object

milligrams (mg)
a unit of mass; equivalent to one-thousandth of a gram

millilitres (mL)
the unit of volume used to measure small or exact quantities of liquids; equivalent to one-thousandth of a litre

millimetres (mm)
a unit of length used to measure short distances; equivalent to one-thousandth of a metre

mineral
a naturally occurring solid substance with its own chemical composition, structure and properties

mitochondrion
the powerhouse organelle of a cell; the site of the site of cellular respiration (energy production) (plural *mitochondria*)

mitosis
a type of cell division that produces identical daughter cells for growth or repair

mixture
something made up of two or more pure substances mixed together

molecular compound
atoms of two or more different elements that are chemically bonded together

molecular element
atoms of one element chemically bonded together

monatomic molecule
a molecule that consists of one atom

monotreme
a mammal that lays eggs

multicellular
any living thing with more than one cell

mutagen
a substance that may damage a cell's genetic material (DNA)

mutualism
a symbiotic relationship in which both organisms benefit

mycologist
a scientist who studies the Kingdom Fungi

N

natural flora
microbes that live happily in our bodies

nephron
a tiny structure in the kidneys that filters the blood

net force
a combination of all the forces acting on an object

newton
unit used to measure force; symbol N

noble gas
a collection of gaseous elements found in group 18 of the periodic table

non-contact force
a force that operates between two objects when they are not touching each other, e.g. gravitational force

non-living
something that has never had the characteristics of a living thing

non-metal
a collection of elements that are found on the right-hand side of the periodic table

non-renewable resource
a resource that is limited because, once used, it takes a long time to replace

non-vascular
(in plants) lack transport vessels

normal force
the force of a surface pushing back on another when contact is made

nuclear potential energy
energy stored at the centre of atoms

nucleus
the control centre of a cell that contains all the genetic material (DNA) for that cell

nutrient
a soluble substance that an organism needs to live and grow; usually taken in from the environment

O

objective lens
the lens closest to the specimen

observation
using all your senses to notice things around you

oestrogen
a hormone that promotes the development and maintenance of female characteristics of the body

omnivore
an animal that eats both plants and animals

onion skin weathering
the process of weathering of rock where the outside of the rock peels off

orbit
the path taken by planets

order
a level of taxonomic classification below class and above family

ore
a mineral containing a large amount of useful metal or valuable mineral

organ
a group of different tissues that are self-contained and have a specific vital function

organelle
a smaller part of a cell, each having a different function

osmosis
the movement of water through a selective membrane from an area of low 'salt' concentration to an area of high 'salt' concentration; occurs in root cells

ovary
the enlarged basal portion of the carpel that contains the ovum

ovulation
the release of an egg from an ovary

ovum
female gamete of flowering plants

P

palaeontologist
a scientist who studies fossils

parallax error
an error that occurs when reading a scale from an angle

parasitism
a symbiotic relationship in which one organism (parasite) benefits and the other (host) is harmed but not usually killed

parent cell
the cell from which other cells develop during cell division

partial eclipse
when only some of the Sun's light is blocked by the Moon

particle model of matter
theory that all matter is made up of very tiny particles

pathogen
a microbe that can potentially cause a disease

period
a horizontal list of elements found on the periodic table

periodic table
a table that arranges all the elements in order of the number of protons that the atom has in its nucleus

peristalsis
when muscles behind the food squeeze tight and the muscles in front of the food relax, causing the food to move along the throat or intestines

pharynx
the throat that connects the mouth to the oesophagus

phases of the Moon
changes in the shape of the Moon visible on Earth

phloem
the vascular tissue found in plant stems that carry sugars around the plant

photosynthesis
the chemical process plants use to make glucose and oxygen from carbon dioxide and water

photovoltaic cell (PVC)
an electrical device that converts light energy into electrical energy; see solar cell

phylum
a level of taxonomic classification below kingdom and above class

physical property
can be measured or observed without changing a substance into something else, e.g. colour, boiling point

placental mammal
a type of mammal that carries the fetus in a placenta

plankton
microscopic organisms the float in fresh or salt water

pollen
male gamete of a flowering plant

pollination
the transfer of pollen (male gamete) to a stigma (female structure)

polymer
a chemical compound with molecules made of groups of atoms that repeat over and over

population
all the inhabitants of a particular habitiat

potential energy
energy that is stored in objects

power station
a place where energy is converted into electricity

precipitation
the process in which water vapour in the upper atmosphere becomes liquid water in the form of rain, snow or sleet and falls to the ground

predator
an organism that kills and eats other animals (prey)

prediction
the expected result of an experiment

prey
an organism that is killed and eaten by a predator

producer
a plant or plant-like organism found at the start of a food chain

product
substance you finish with in a chemical reaction

prokaryotic cell
a primitive single-celled organism that has no nucleus

property
(in geology) a characteristic of a rock; (in chemistry) a characteristic or thing that makes something unique

proton
a particle in an atom with a positive charge

pure substance
something that only contains one type of substance

Q

qualitative observation
an observation that uses words and is not based on measurement or other data

quantitative observation
an observation that uses a number, such as a measurement

R

radiation
the transfer of thermal energy (via photons) across empty space or through another substance

radioactive dating
the process of calculating the age of rocks by comparing the amounts of uranium and lead they contain

reactant
substance you start with in a chemical reaction

recycling
the process of turning waste into new materials

renewable resource
a resource that is made naturally and is available in an almost unlimited amount

repulsion force
a force that pushes one object away from another

residue
the substance left behind in a sieve or filter

results
measurements and observations taken in an experiment

ribosome
a cell structure where protein production takes place

rock cycle
the process of formation and destruction of different rock types

S

saturated
a solution in which no more solute can be dissolved

scatter graph
a graph used to represent continuous data; it consists of discrete data points

science
the study of the natural and physical world

scientific diagram
a clear, side view, labelled drawing made using a sharp pencil

scientist
a person who studies the natural and physical world

secondary source
a scholarly book or article written by an author who did not obtain primary data or evidence first-hand

sclerophyll
a woody plant with evergreen leaves that are tough and thick in order to reduce water loss

sediment
something that settles to the bottom in a mixture

sedimentary rock
rock formed from compacted mud, sand or pebbles, or the remains of living things

sedimentation
a process that uses gravity to remove suspended solids from a solution

selective breeding
the breeding of two individuals chosen for for their particular traits

self-pollination
the pollination of a flower by pollen from the same flower or from another flower on the same plant

series circuit
the positioning of loads (lights) side by side in an electric circuit so that the electrical energy passes though one load at a time

sexually dimorphic
those species in which the male and female organisms look structurally different

sieving
a separation technique used to separate different-sized particles depending on the holes in the sieve used

single-celled
consisting of one cell

solar cell
a cell that converts sunlight into electrical energyl

solar eclipse
when the light from the Sun is blocked by the Moon

solar energy
energy made by atoms colliding with one another in the centre of the Sun

solar power
energy from the Sun

solar system
the system made up of the Sun and all the planets, dwarf planets, moons and asteroids that travel around the Sun or each other

solubility
how easily a substance dissolves in a solvent

soluble
can be dissolved in a liquid

solute
a substance that dissolves in a liquid (solvent)

solution
a liquid made up of a solvent with a solute dissolved in it

solvent
any liquid that dissolves other substances

somatic cell
all body cells except for gametes

sound energy
type of kinetic energy made when things vibrate

species
a group of individuals that can breed and produce viable, fertile offspring

spring balance
a device consisting of a spring and a scale, used to measure forces in the laboratory

stamen
male reproductive structures in a flowering plant

stem
a plant organ involved in transporting sugars, water and nutrients

stereomicroscope
a microscope with two eyepieces that uses low magnification

stigma
the part of the female reproductive structure in flowering plants; the tip of the carpel where pollen is deposited

stimulus
any information that the body receives that causes the body to respond

streak
the colour of powdered or crushed mineral

streamlining
making a surface smooth and rounded to reduce friction

sublimation
the process of becoming a gas from a solid, bypassing the liquid phase

substance
a solid or liquid that can be mixed

surface area to volume ratio
the relationship between the area around the outside of a cell and its volume as a fraction

suspension
a cloudy liquid that contains insoluble particles

symbiosis
an ongoing close relationship between two organisms; mutualism, commensalism or parasitism

symptom
a change that occurs to an individual as a consequence of a disease

T

taxonomist
a scientist who classifies living things into groups

tectonic plate
a massive slab of rock that forms part of the lithosphere

telescope
an optical instrument that uses lenses and mirrors to make distant objects appear closer and larger

tendon
a type of connective tissue that connects muscle to bone

tensile strength
the measure of the flexibility of the links or bonds between particles

testosterone
a hormone that stimulates development of male secondary sexual characteristics

theory
an explanation of a small part of the natural world that is supported by a large body of evidence

thermal energy
scientific term for heat energy

thermal equilibrium
when two systems are at the same temperature; no heat moves from one system to another

tidal energy
energy produced using the tides to drive turbines in the water

tissue
a group of the same cell type that performs a similar task

tor
round rock produced by onion skin weathering

total solar eclipse
when the Moon blocks the maximum amount of light from the Sun

trachea
the large tube that connects the throat to the bronchi; carries air in and out of the body

transferred
said of energy that has moved from one object to another

transpiration
the process by which plants take up water from the soil through their roots and up into their leaves

tumour
a growth or lump caused by a cell growing out of control

turbine
a large wheel with angled sections called vanes, like a propeller, that is used to generate electricity

U

unbalanced forces
two or more forces that are unequal in size and direction and therefore change an object's speed, direction or shape

unicellular
living things consisting of one cell (such as bacteria)

unit
a standard measurement

unlike poles
opposite poles of magnets

urban sprawl
the spread of urban areas into rural areas

urbanisation
the process of making an area more urban

urea
a form of nitrogen waste product formed by the body

V

vacuole
a large fluid-containing space or vesicle, a membrane-bound organelle in a cell

vaporise
to change state from a liquid to a gas; same as to evaporate

vapour
gaseous form of a substance

variable
the something that can affect the results of an experiment

vascular tissue
(in plants) tube-like structures that transport water from the roots to the leaves

vascular bundle
groups of tubes found in plant stems that carry water and nutrients around the plant

vector
a carrier that can transfer an infectious pathogen from one host to another

vegetative reproduction
asexual reproduction in plants where identical offspring are grown form the tissue of a parent plant

vein
a thin blood vessel that carries blood back to the heart

vertebrate
an organism with an endoskeleton (internal skeleton)

villi
small ridges found in the small intestine that absorb nutrients from the digestive system

viscosity
a measure of how slowly a liquid changes its shape; the thickness of a liquid

volatile
when a substance evaporates to become a gas at room temperature

volcano
a vent or hole in the Earth where molten (melted) rock ash and other materials escape onto the surface

volume
how much space an object takes up, usually measured in litres (L) or millilitres (mL)

W

water cycle
the cycle of constant evaporation and precipitation that occurs in nature

water vapour
water in the gaseous state

wave energy
energy produced using the power of waves to drive air turbines

weathering
the breakdown of rocks and minerals by the movement of water and animals, and extremes of temperature

weight
a measure of how much gravity is pulling on an object

wet cell
an object, such as a car battery, that uses a chemical reaction to produce electrical energy

wind farm
a large group of wind turbines in the same location

wind turbine
a wheel with blades that turns in the wind

X

xylem
the tissue in plants that carries water from the roots to the rest of the plant

Y

yield
the amount produced

Z

zoologist
a scientist who studies the behaviour, physiology, classification and distribution of animals

zygote
the first cell of a new organism after fertilisation

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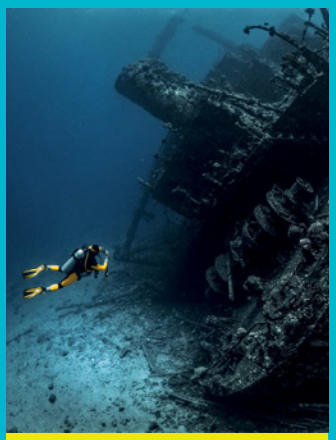
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A scuba diver observing a rusted and overgrown shipwreck in the Red Sea. The average water temperature of the Red Sea is 22°C; wearing a wetsuit helps the scuba diver's internal systems continue to function while exploring the ocean. Over time, shipwrecks corrode. This corrosion, combined with the structure of the ship itself, can provide habitats for a variety of marine life including fish, crabs, sea anemones and coral. Shipwrecks are common throughout the Red Sea, particularly on coral shelves.

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