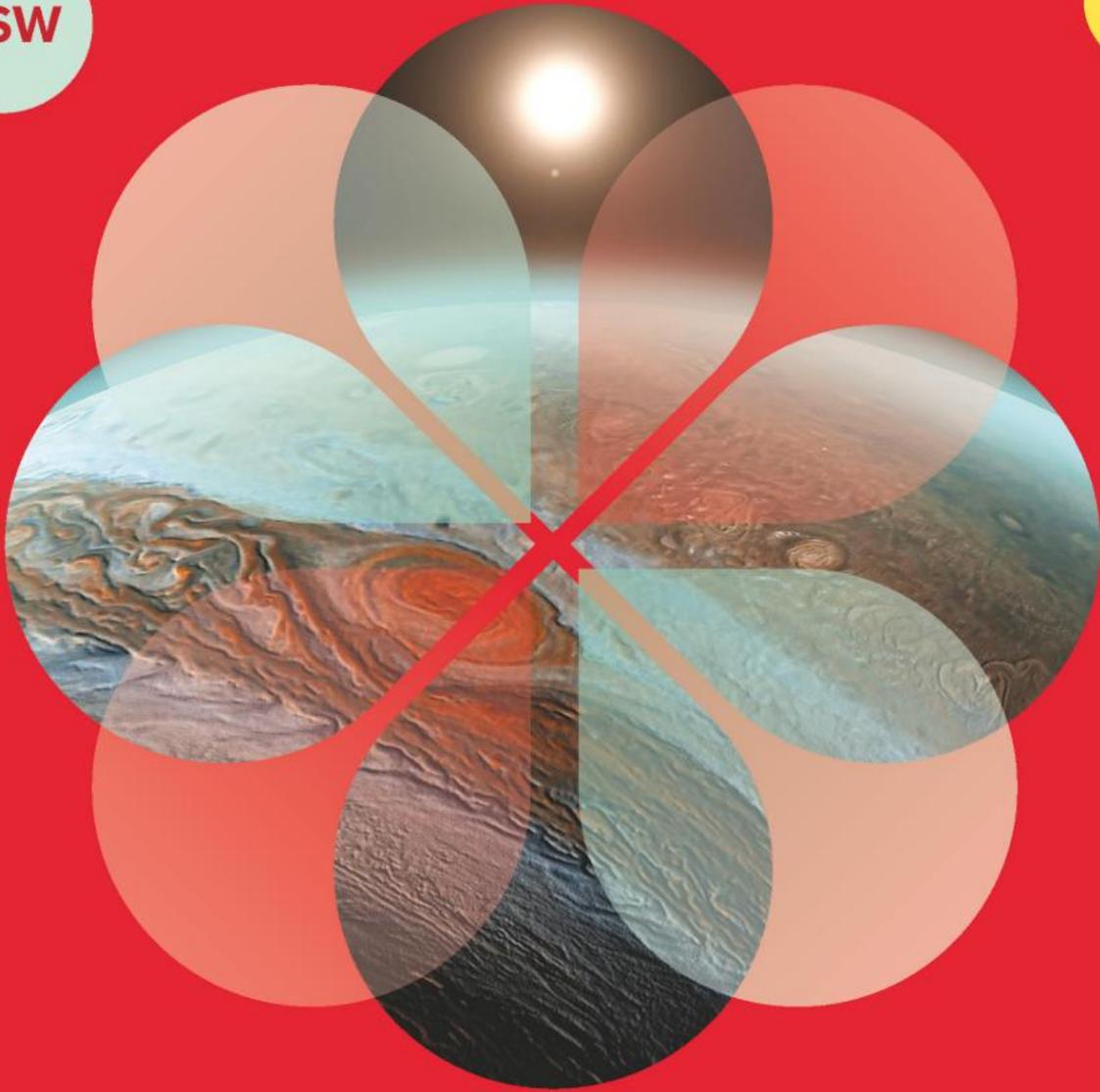


NSW



SCIENCE IN FOCUS

STAGE 4

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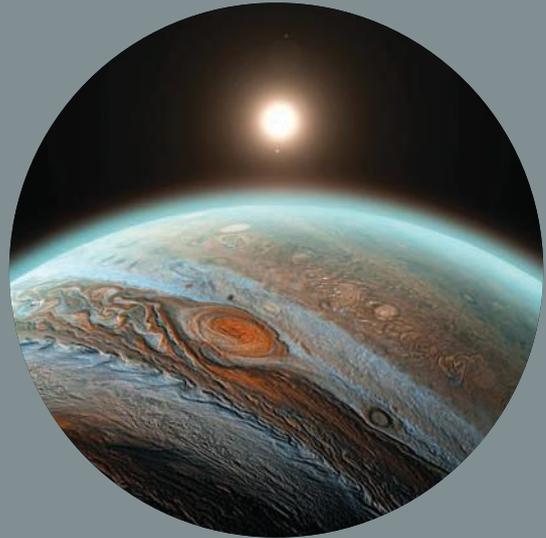
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LEARNING DISCOVERY
JUPITER



This cover image shows Jupiter, the largest planet in our solar system. This gas giant spins very quickly, with a day lasting about 10 hours. Jupiter has no solid surface and 95 moons.

The Great Red Spot you can see in this photo has been observed by scientists for more than 300 years. It is a giant storm that has been raging for centuries in Jupiter's cloudy and very windy atmosphere.

Science in Focus Stage 4 NSW

1st edition

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ACKNOWLEDGEMENT OF COUNTRY

**Nelson acknowledges
the Traditional Owners and
Custodians of the lands of
all Aboriginal and Torres Strait
Islander Peoples of Australia.
We pay respect to their Elders past
and present.**

**We recognise the continuing
connection of Aboriginal and
Torres Strait Islander Peoples
to the land, air and waters, and
thank them for protecting
these lands, waters and
ecosystems since
time immemorial.**

ABORIGINAL AND TORRES STRAIT ISLANDER PEOPLES GLOSSARY

Country/Place

Spaces mapped out that individuals or groups of Aboriginal and Torres Strait Islander Peoples of Australia occupy and regard as their own and that have varying degrees of spirituality. These spaces include lands, waters and sky.

Cultural narrative

A broad term that encompasses any cultural expression that includes (but is not limited to) knowledge and community values that are central to the identity of a particular group of Aboriginal and Torres Strait Islander Peoples.

Cultural narratives can hold information about almost anything, such as the origins of life, or can teach people about acceptable behaviour and rules, such as caring for Country. They can take the form of songs, stories, visual arts or performances. 'Cultural narrative' is a more accurate and respectful term than 'myth', 'story' or 'fable', terms that often diminish their importance.

Nation

A self-governed community of people based on a common language, culture and territory.

Peoples and Nations

We use the plural for these terms because Aboriginal and Torres Strait Islander Peoples do not belong to one nation/culture. There are many distinct Peoples and Nations. Also, some Nations consist of distinct clans or groups, so are referred to as Peoples.

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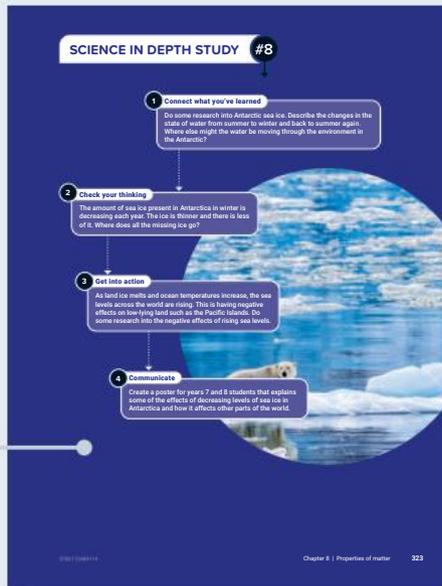
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How to use this book



Science in depth: The opening page begins the chapter by placing the science topic into a real-life context that is both interesting and relevant to our lives.

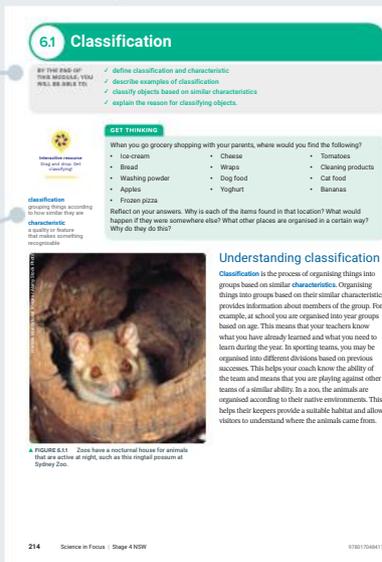


Think, do, communicate: In the Science in Depth Study you are encouraged to reflect on and apply your learning to a set of activities, which allows you to make meaningful connections with the content and skills you have just learned.

Learning modules: Content is chunked into key concepts for effective teaching and learning.

Learning objectives: Clear, concise learning objectives give you oversight of what you are learning and set you up for success.

Key words: Key words are defined the first time they appear.



To be effective, a classification system must use the right kinds of characteristics. Each characteristic should be:

- observable so that it can be easily identified
- consistent so that the object will always be classified in the same way
- related to the reason for classification so that the information is valid.

There are many reasons for classifying things, and the reason will determine the way that they are classified. For example, food may be classified as:

- savoury or sweet
- containing gluten or gluten-free
- eaten when hot, cold or at room temperature
- fresh or processed
- cereal, dairy, fruit and vegetable or meat.



6.3 LEARNING CHECK

- 1 **Define classification.**
- 2 What characteristics would you use to help a person identify vanilla ice-cream who has never eaten it? Choose all options that apply.
 - a It is sweet.
 - b It is served on a plate.
 - c It is eaten cold.
 - d It smells and tastes like vanilla.
- 3 **Describe** how cutlery (knives, forks and spoons) is organised in your kitchen drawer. **Explain** why it is arranged this way.
- 4 Use the photo to **classify** buttons. **State** the characteristics of the buttons that you would use to classify the buttons into:
 - a two groups.
 - b more than two groups.
- 5 **Discuss** the advantages of classifying car drivers into learners (L), drivers (D), provisional (P) and open (full) licence.



Learning check: These are engaging activities to check your understanding. Activities are presented in order of increasing complexity to help you confidently achieve the module's learning objectives. **Bolded** cognitive verbs help you clearly identify what is required of you.

Aboriginal and Torres Strait Islander Science Contexts: This content was developed in consultation with a First Nations Australian curriculum specialist. It showcases the key connections between Science and Aboriginal and Torres Strait Islander Peoples' Cultural Knowledges, with authentic, engaging and culturally appropriate science content.

Science in Context: The NSW Science syllabus is explicitly addressed with interesting, contemporary content and activities.

18.12 Dealing with acid mine water

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- explain why mines need to be carefully rehabilitated to prevent damage to creeks and waterways.

Acid mine drainage

Figure 18.12.1 shows a mine in Spain called the Rio Tinto. There is little life in the river and its colour comes from minerals dissolved in the acidic river water. How did the river come to be like this, and how can we prevent similar fates for our waterways?

Copper is an example of a valuable resource that we extract from the earth. The most commonly mined copper minerals are chalcopyrite (CuFeS₂) and chalcocite (Cu₂S). These are called sulfides because the metals are combined with the element sulfur. The Rio Tinto River drains an area where a huge amount of sulfide ore was located.

Acid mine drainage is an environmental problem. It is caused when sulfide minerals contact oxygen in the air. The minerals weather, producing compounds of sulfur and oxygen called sulfur oxides. When these oxides dissolve, they react with water and form acids. The acidic water will damage life in rivers and creeks if it escapes out of the mine. The acid mine water is also capable of dissolving elements such as copper, zinc, arsenic, cadmium and lead. These metals can end up in plants and animals and, over time, may cause illness and death.

Mine rehabilitation is the process undertaken by scientists and engineers to clean up a mining area. Mining can cause damage to the environment, so it is important to clean up or rehabilitate mining sites after they are closed. Mine clean-up is incredibly important to reduce the impact that mining has on the environment. For example, it involves treating any acidic water the mine has produced so that rivers are not polluted. The cost of treating acid mine drainage is high but the cost of damaging the environment is even higher.

LEARNING CHECK

- Describe the steps in which acidic, metal-rich mine water is produced/formed.
- Explain why drainage from acid mines should not be allowed to enter rivers or streams.
- The Rio Tinto River receives water from areas that have been mined for 5000 years. In previous times, why did the miners not take steps to prevent the discharge of acid mine waters?

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5.13 Spear-throwing technology

ABORIGINAL & TORRES STRAIT ISLANDER SCIENCE CONTEXTS

IN THIS MODULE, YOU WILL:

- investigate the use of forces in spear-throwers developed or used by Aboriginal and Torres Strait Islander Peoples

Examining spear-throwers

Aboriginal and Torres Strait Islander Peoples developed and produced a range of tools designed to increase both the speed and accuracy of hunting projectiles, such as spears and arrows. Across much of Australia, many Aboriginal and Torres Strait Islander Peoples developed, used or refined spear-throwers. Peoples of the Torres Strait used bows and arrows as well as spear-throwers.

There is evidence that Aboriginal Peoples began to manufacture and use spear-throwers at least 5000 years ago and that the development of this hunting technology is similar to that of other First Nations Peoples of the world.

Spear-thrower technology highlights Aboriginal and Torres Strait Islander Peoples' understanding of forces and levers. A spear-thrower helps hunters throw further by acting as an extension of the thrower's arm. A longer 'arm' (or longer lever) means that more force can be put behind the spear and it can fly faster and further.

Spear-throwers are crafted out of wood, usually hardwood such as mungli. However, the shape, width and length vary depending on the cultural group's design (Figure 5.13.1) and the environment in which it was used. Each spear-thrower needs to be carefully constructed for its individual user to maximise its effect when used.

Spear-throwers typically narrow towards the gripping end where notches coated in resin are cut into either side to form a hand grip (Figure 5.13.2a). The other end has a 'peg' (Figure 5.13.2b), often made from a different material, that fits into a socket or notch at the base of the spear.

ACTIVITY

- Draw a labelled force diagram to show the forces acting on a spear:
 - when it is resting in the spear-thrower (before being thrown),
 - in motion through the air after being thrown.
- For the diagrams you drew in Question 1, explain if the forces are balanced or unbalanced.
- Describe what advantages the spear-throwers give to the hunters.
- Explain how the spear-throwers give these advantages. (Hint: Spear-throwers are levers.)

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Science skills in focus: Each chapter focuses on specific working scientifically skills. These are explained and modelled with our 'Science skills in a minute' video, before you put it into practice in a science investigation. The science skill is reinforced with our 'Science skills in practice' digital activities.

Activities: Activities are open-ended and often practical, allowing you to understand the Aboriginal and Torres Strait Islander Peoples' cultural and historical connections to science.

WORKING SCIENTIFICALLY

3.9 Practise using laboratory equipment

SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS

- practising using laboratory equipment

Lab equipment tips

Here are some general pointers to help you use laboratory equipment correctly and safely.

- Check the materials listed in the Materials and equipment section. Do you have everything?
- Always ensure equipment is clean and dry before you use it.
- Take care when using fragile equipment, such as glassware.
- Let your teacher know if you accidentally damage or break equipment.
- Make sure you are careful when pouring and measuring liquids.

Measurements when ice is added to water

AIM

To use science equipment to measure the temperature change when an ice cube melts in water

MATERIALS AND EQUIPMENT

- water (approximately 150 mL)
- 2 × 250 mL beakers
- 200 mL measuring cylinder
- ice cube made from water with food dye
- electronic balance
- thermometer or temperature probe
- stopwatch or timer on a device

PROCEDURE

- Use a measuring cylinder to measure 150 mL of water. Record this volume in a results table like the one on the next page.
- Pour the water into a beaker.
- Use the thermometer (or temperature probe) to measure the temperature of the water. Record the temperature in the results table.
- Place the second beaker on the electronic balance and press zero (or tare) so that the reading is 0.00 g.
- Add one ice cube to the beaker to measure its mass. Record the mass in the results table.
- Prepare the stopwatch (or timer) so that it is ready to start timing.
- Add the ice cube to the water and start the stopwatch (or timer) (Figure 3.9.1).
- Stop the stopwatch (or timer) as soon as the ice has melted. Record this time in the results table.
- Use the thermometer (or temperature probe) to measure the temperature of the water when the ice cube has melted. Record this final temperature in the results table.
- Pour the water down the sink and rinse your equipment before packing it away.

FIGURE 3.9.1 The coloured ice cube is added to the water.

RESULTS

- Copy and complete the results table below.
- List five observations that you made during the experiment.

Description	Measurement
Volume of water (mL)	
Initial temperature of water (°C)	
Mass of ice cube (g)	
Time for ice cube to melt (mins)	
Final temperature of water (°C)	

ANALYSIS

- Why do you think the ice cube melted?
- How many degrees Celsius did the temperature of the water change by?
- What do you think would have happened if:
 - you had used a smaller volume of water?
 - the ice cube had a bigger mass?
 - the ice cube had been crushed?
- What steps did you take so that your measurements were as accurate as possible?

CONCLUSION

What did you learn in this activity?

9780170484114 Chapter 3 | Nature and practice of science 125 126 Science in Focus | Stage 4 NSW 9780170484114

Investigations: Practise and reinforce working scientifically skills through fit-for-purpose and engaging science investigations.

1

Working scientifically

1.1 Introducing the working scientifically processes (p. 3)

The scientific processes are a cycle of steps to obtain valid information in a consistent and repeatable manner to answer scientific questions.

1.2 Observing (p. 6)

An observation is any information gained using the senses or measuring instruments.

1.4 Questioning and predicting (p. 12)

Scientific questions are objective and testable ideas used to make predictions about an investigation.

1.3 Variables (p. 9)

Variables are factors that could change a result. They are classified as independent, dependent or controlled variables.

1.5 Planning investigations: identifying purpose and variables (p. 16)

The purpose of an investigation determines how the investigation is planned and conducted.

1.6 Planning investigations: methods (p. 18)

Procedures and methods are the sets of steps that someone follows to conduct a scientific investigation.

1.8 Conducting investigations: equipment (p. 26)

Scientists use specialised equipment to conduct experiments and collect data.

1.7 Planning investigations: safety (p. 22)

Rules must be followed to stay safe before, during and after an investigation.

1.9 Conducting investigations: recording data (p. 30)

Data collected during investigations can be recorded in tables ready for further processing and analysis.

1.10 Processing data and information (p. 32)

Collected data can be organised and presented in many ways, such as graphs and charts. Graphs allow you to identify trends and patterns.

1.12 Problem-solving in science (p. 40)

Solving problems during investigations requires the use of strategies to identify cause-and-effect relationships.

1.11 Analysing data and information (p. 36)

Trends and patterns are analysed to determine if a scientific question has been answered.

1.13 Communicating: planning and writing scientific texts (p. 44)

Scientists share their findings in formats suited to specific audiences.

1.14 Communicating: scientific reports (p. 47)

Scientific reports follow a specific format and scientific language conventions.

1.15 Depth studies (p. 52)

A depth study is individual or collaborative research conducted to investigate scientific concepts in depth.

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ list the working scientifically processes
- ✓ explain the importance of working scientifically.

GET THINKING

Figure 1.1.2 (on the next page) illustrates the steps scientists follow when they plan and conduct science investigations. Use the first letter of each word to create a saying to remember the steps. The saying does not need to be serious or factual – just something that you will remember. These sayings are called **mnemonics** and are a strategy to help remember a list of words.

mnemonic

a memory aid that uses the pattern of letters in words

The scientific processes

Scientists are constantly discovering new information about our world and the universe. The information they discover can only be trusted if they carry out research using a reliable and fair process.

Imagine if you investigated which colour car was the fastest, using the cars in Figure 1.1.1. Based on the results, you concluded that red cars are the fastest cars. However, there were many differences (factors) that affected how quickly the cars in your investigation could go. These factors include the age, shape, mass and size of the car, its motor, and the road surface. Therefore, the investigation was not a **fair test**, and its results cannot be trusted.

fair test

an investigation that is conducted correctly to answer a scientific question

Charlie Hutton/Shutterstock.com



Whitevector/Shutterstock.com



Dimitris Leonidas/Shutterstock.com



Rob Wilson/Shutterstock.com



▲ **FIGURE 1.1.1** A range of cars used in an investigation to find out which colour of car is the fastest

scientific processes
steps involved in working scientifically

hypothesis
a testable explanation for something based on existing knowledge; a testable statement of the predicted relationship between the independent and dependent variables

conclusion
a judgement reached by reasoning

Scientists work scientifically by following **scientific processes** (Figure 1.1.2) to plan and conduct their investigations. You will sometimes see this called the ‘scientific method’. The scientific processes are a series of steps used to plan and conduct experiments in a consistent and repeatable way. The working scientifically processes are:

- 1 Observing – using your senses to gather information about the world
- 2 Questioning and predicting – developing a testable scientific question and predicting reasons for your observations (a **hypothesis**)
- 3 Planning investigations – creating a series of procedures to test your question
- 4 Conducting investigations – following procedures to collect data and information in a systematic way
- 5 Processing data – organising your data into tables, graphs or diagrams
- 6 Analysing data – assessing your data by comparing it to the original observations and predictions and drawing **conclusions** to evaluate the investigation
- 7 Problem-solving – using strategies to find solutions to problems
- 8 Communicating – presenting your findings to different audiences.



▲ **FIGURE 1.1.2** The working scientifically processes scientists use to plan and conduct investigations

The working scientifically processes are shown as a cycle in Figure 1.1.2 because scientists reflect, revise and repeat these steps. In this chapter, you will learn more about each of the scientific processes.

Using scientific processes

An example of using scientific processes is choosing the better type of coffee cup to keep coffee hot (Figure 1.1.3). The processes used are summarised in Figure 1.1.4.



Video activity
What are the scientific processes?

Interactive resource
Label: Scientific processes

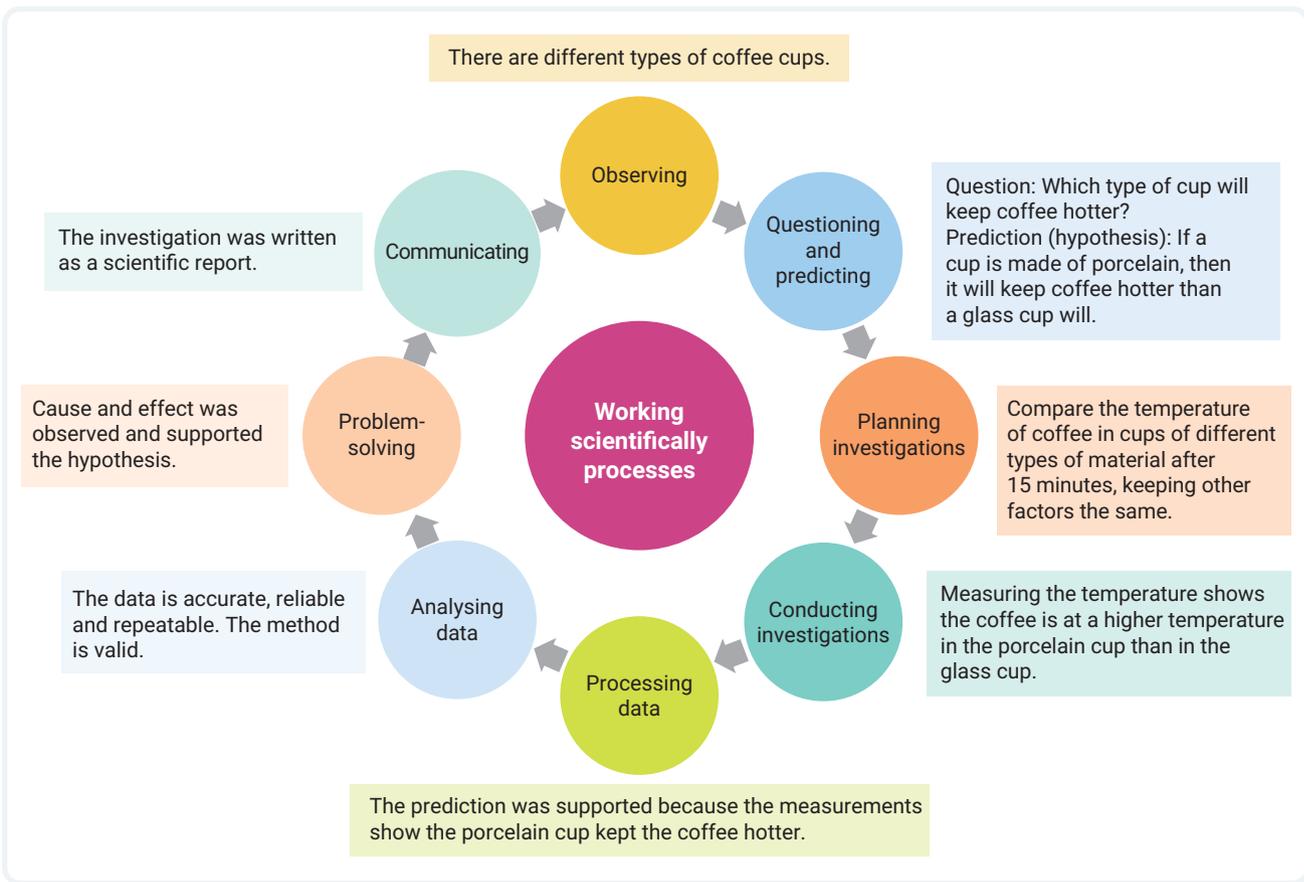


tanuha2001/Shutterstock.com



Sergey Peterman/Shutterstock.com

▲ FIGURE 1.1.3 Which type of coffee cup will keep coffee hotter?



▲ FIGURE 1.1.4 The processes in working scientifically to test which coffee cup will keep coffee hotter

1.1 LEARNING CHECK

- 1 List** the working scientifically processes.
- 2 Explain** why the working scientifically processes are represented as a cycle.
- 3 Outline** the steps that you would take to test which fly repellent is the most effective.
- The scientific processes are used by scientists around the world. **Explain** why it is important for all scientists to use the same processes.

1.2

Observing

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define observation and inference
- ✓ list the senses that are used to collect observations
- ✓ give examples of observations and inferences in different scenarios
- ✓ classify statements as either observations or inferences
- ✓ use observations to make inferences.



Quiz
Observations and inferences

GET THINKING

How well can you describe your pencil case?

Imagine that you lost your pencil case and needed to describe it to your teacher so that it can be identified from all the pencil cases in lost property. Write a description that is thorough enough for there to be no doubt which pencil case is yours.

observation

data collected through the senses (sight, smell, taste, touch or hearing) or with measuring tools

An **observation** is any information gained directly from our senses or measuring instruments. You will learn about measuring instruments in Module 1.8.

In primary school you learned about the senses – sight, smell, taste, touch and hearing. We use our senses in science to collect information about whatever we are studying. For example, a scientist who is studying chemistry would make observations such as the colour of a substance, whether bubbles are produced, the odour of a liquid and whether the container gets hotter or colder.

Qualitative observations

When we use our senses to collect data, we are making qualitative observations. The information that we collect is called **qualitative data** and is usually in the form of a description. The following are all examples of qualitative data.

- A dark blue colour
- A sweet smell
- Feels hot to touch
- A colourless liquid
- A smooth surface
- Able to be squashed
- A loud bang

qualitative data

non-numerical information that relates to a quality, type, choice or opinion

Quantitative observations

Quantitative observations are numbers and we call them **quantitative data**. This may be a counting number, such as five petals, or a measurement, such as 14 cm long. Other examples of quantitative data are the temperature of a pond, the time it takes for rubbish to decompose, the volume of oxygen produced by plants and the force needed to bend a piece of metal.

quantitative data

numerical information that is counted or measured and expressed as numbers

Table 1.2.1 summarises the features of qualitative and quantitative observations.



▲ FIGURE 1.2.1 Scientists use their senses to make observations: (a) seeing the shape of grass seeds; (b) conducting a blind smell test; (c) touching tomatoes; (d) listening to the heartbeat of an unborn baby.

▼ TABLE 1.2.1 The differences between qualitative and quantitative observations

	Qualitative observations	Quantitative observations
Description	Think: qualitative = quality Observations are based on senses: smell, colour, taste, physical appearance, hardness, texture.	Think: quantitative = quantity Observations are based on numbers, which come from counting and measurements.
Example: A Year 7 class	<ul style="list-style-type: none"> • The students are friendly. • The students have different coloured eyes. • The students are noisy. • The students wear blue uniforms. 	<ul style="list-style-type: none"> • There are 26 students in the class. • 16 students have brown eyes and 10 have blue eyes. • The students are aged 12, 13 or 14.

The power of observations

Art is a powerful and creative way to express complex ideas and emotions. This is why observing art leads us to think and wonder. Carefully observe the painting in Figure 1.2.2, then answer the questions below.

- 1 How many animals can you observe?
- 2 How many people can you see?
- 3 What themes, ideas or emotions do you see in the painting?
- 4 Compare your observations with those of other people in the class.
- 5 Write a short description of the painting. The description will be used in a promotional flyer for an art gallery.



▲ FIGURE 1.2.2

☆ ACTIVITY

Inferences

inference

a reasonable conclusion based on observations

When you hear a siren, you might guess that there is a fire nearby. You have used an observation (hearing the siren) to make a conclusion about what has happened (a fire). A conclusion based on observations is called an **inference**. If we use more observations to make an inference, it is more likely that the inference will be correct. For example, although hearing a siren might mean a fire engine is going to a fire, it is also possible that it is a police vehicle going to a car accident or an ambulance rushing someone to hospital. However, if it was a hot day and you could smell smoke, then it is more likely that an inference relating to a fire is correct. This is why it is important that scientists collect as much data as possible before making an inference.

1.2 LEARNING CHECK

- 1 **List** five observations about a freshly baked chocolate cake.
- 2 **List** four observations and one inference from the photo below.



- 3 On 9 December 2023, the temperature reached 43.5°C at Sydney airport. Is this a quantitative or qualitative observation? **Use** the relevant definition to support your answer.
- 4 During a police investigation of a burglary, a detective noted that a window frame was damaged. **Write** an inference that could be made from this observation.
- 5 **Explain** how observations and inferences are connected.
- 6 **Discuss** why it is important that doctors make accurate observations when examining a patient.

1.3 Variables

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define variable, independent variable, dependent variable and controlled variables
- ✓ classify variables as independent, dependent or controlled.

GET THINKING

Working in pairs, brainstorm some of the factors that could affect how well you do in the topic test. These ideas are all variables!

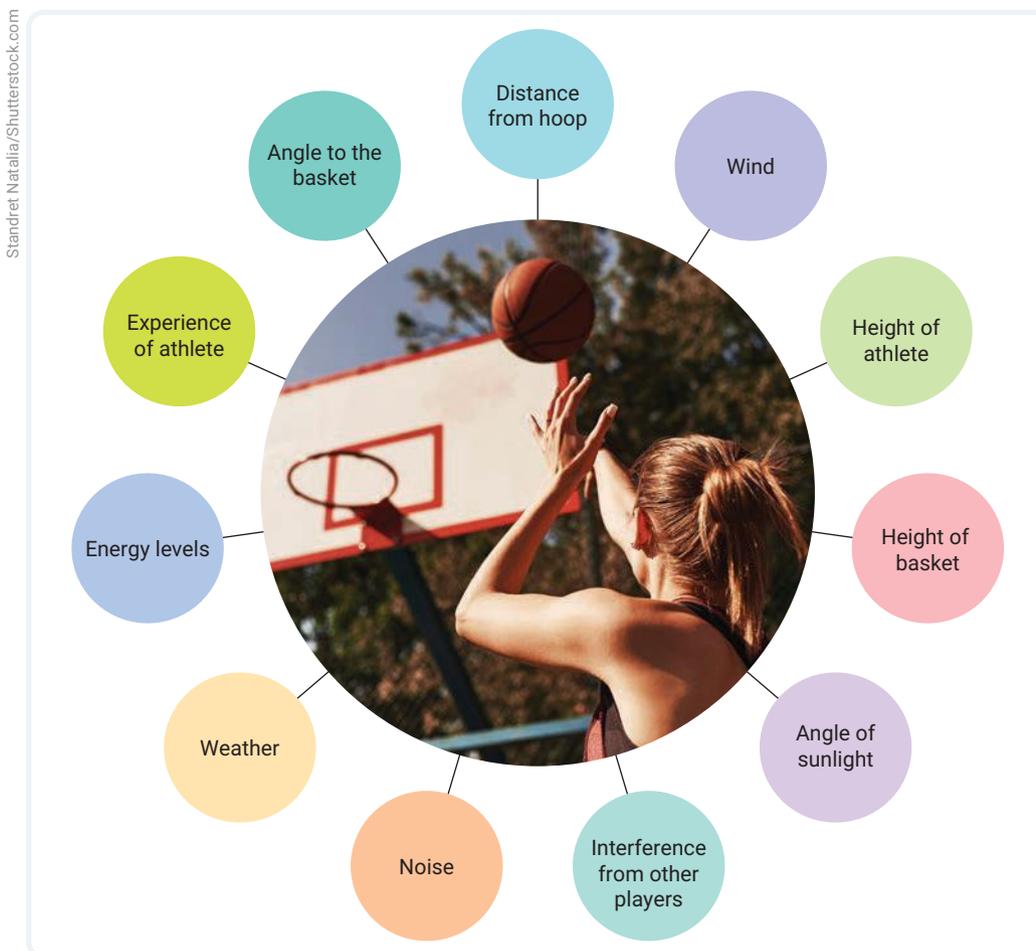


Interactive resource
Drag and drop:
Variables

What are variables?

A **variable** is something that can change. There may be many variables that can affect a particular outcome. For example, Figure 1.3.1 lists some variables related to the chance of successfully throwing a basketball through a hoop.

variable
a factor that could influence the result of an investigation



▲ **FIGURE 1.3.1** Variables that affect the success of throwing a basketball through a hoop

In an investigation or experiment, it is important to plan a fair test where only one variable is changed, and the others are kept the same, or controlled. This means that the investigation will test what you think you are testing, and nothing else should influence the results. You will learn more about fair testing in Module 1.6.

independent variable
the factor that you choose to vary in your investigation

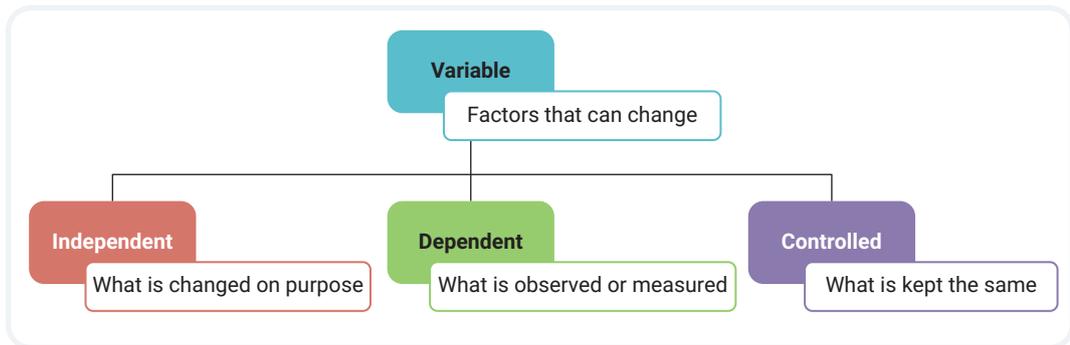
dependent variable
the factor that may be affected by the independent variable; the factor that can be measured or counted

controlled variable
a factor that needs to be kept the same throughout a scientific investigation so that it does not influence the result

Classification of variables

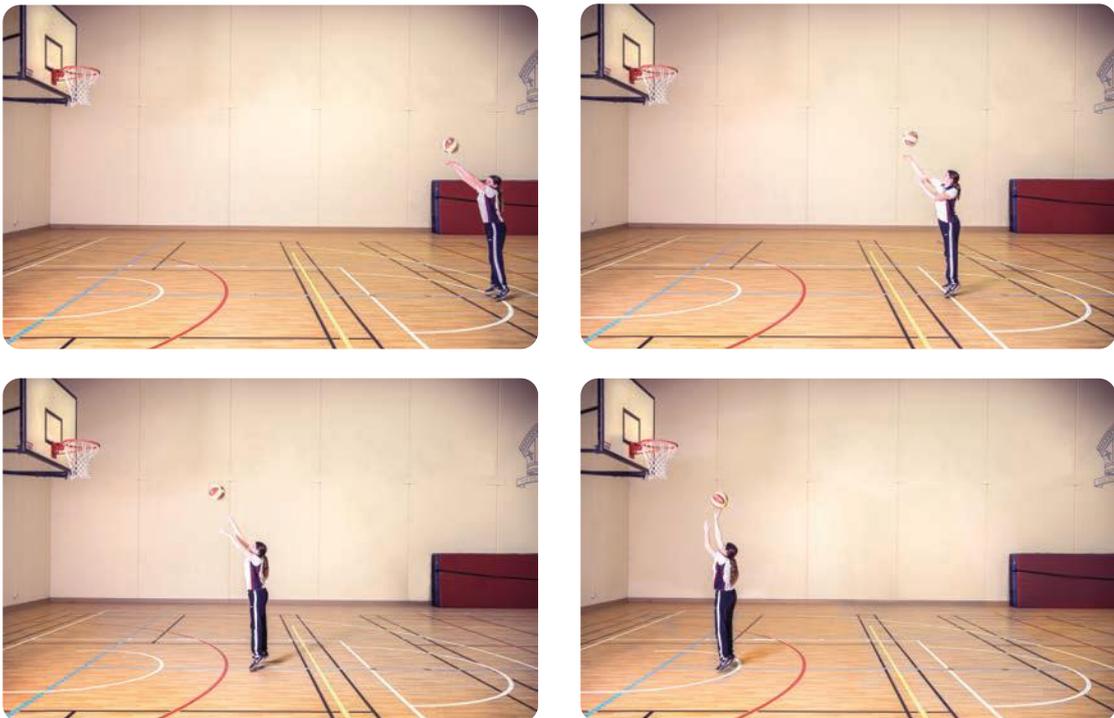
Variables can be classified as independent, dependent or controlled (Figure 1.3.2).

- The **independent variable** is what you choose to change in your experiment.
- The **dependent variable** is what you choose to observe or measure. It may be altered by a change to the independent variable.
- **Controlled variables** are variables that you need to keep the same throughout the experiment.



▲ FIGURE 1.3.2 Classification of variables

In the basketball example, you would choose one variable to change. For example, if you were designing a test for ‘How far away from the hoop should I be when shooting if I want at least an 80% success rate?’, the independent variable is the distance from the hoop (Figure 1.3.3). The dependent variable is whether the basketball goes through the hoop or not, and all the other variables would be controlled. Table 1.3.1 shows some other examples of the types of variables.



▲ FIGURE 1.3.3 The distance from the hoop is the independent variable, and so it is changed while all other variables are kept the same.

▼ TABLE 1.3.1 Examples of different variables in investigations

Type of variable	Definition	Examples		
		Does temperature affect how quickly wheat grows?	Will a heavy ball fall faster than a light ball?	Does water need to be hot to clean oily pans?
Independent	The variable that is changed on purpose	Temperature	Mass of the ball	Temperature of the water
Dependent	The variable that is measured	Rate of growth of wheat, i.e. change in height over time	Time for the ball to fall	How well the pan was cleaned
Controlled	The variables that must be kept constant	<ul style="list-style-type: none"> • Amount (volume) of water • Frequency of watering • Amount (mass) of soil • Size of the pot • Type of soil • Amount (mass or volume) of fertiliser • Type of fertiliser • Amount of sunlight • Number of wheat plants • Depth of planting 	<ul style="list-style-type: none"> • Size of the ball • Smoothness of surface of the ball • Height that the ball was dropped from • Accuracy of timer • Person timing 	<ul style="list-style-type: none"> • Volume of water • Volume of oil on the pan • Type of oil on the pan • Type of detergent used • Volume of detergent used • Time spent cleaning • Method of cleaning/scrubbing • Size and shape of the pan

1.3 LEARNING CHECK

1 Define:

- a independent variable.
- b dependent variable.
- c controlled variable.

2 A toy manufacturer was testing the strength of plastic by measuring the force required to break it. **State:**

- a the independent variable.
- b the dependent variable.
- c three controlled variables.

3 Choose a scientific question that you could test at school. **List** the independent variable, dependent variable and four controlled variables for the investigation.

4 Explain why a fair test only changes one variable.

5 Create a silly saying to remember the classification of variables. For example, 'At the zoo I changed direction to find the **D**ingo but **C**ouldn't'. This phrase links I (for independent) with changing, D (for dependent) with finding and C (for controlled) with couldn't.

1.4 Questioning and predicting

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define testable question, hypothesis and prediction
- ✓ develop a testable question from an observation
- ✓ write testable hypotheses
- ✓ identify the independent and dependent variables from a hypothesis.



Quiz

Questions, hypotheses and predictions

Extra science investigation

Popcorn hypothesis

GET THINKING

Study the bees feeding on the flower shown in Figure 1.4.1.

- 1 What do you observe?
- 2 Write a question related to your observation that could be tested.
- 3 Write a possible answer to your question.
- 4 What results do you think you would get if you tested your question?



▲ FIGURE 1.4.1 Bees feeding on a flower

The first two stages that scientists use at the beginning of an investigation are:

- 1 Ask a testable question about an observation.
- 2 Formulate a prediction and a hypothesis.

Making an observation and asking a question

We are constantly making observations about the world around us. Sometimes, an observation leads us to ask questions. For example, you may have seen chefs add salt to a saucepan of water that is being heated on a stove. Based on this, you might make the following observation and ask a question.

Observation: Salt is added to water being heated.

Question: Will water boil more quickly if salt is added to it?

Testable questions

The **testable question** drives the investigation. We refer to the question when we plan and conduct the research. But how do we make sure our question is testable?

To be testable, a question must:

- be relevant to the investigation and based on observations
- include the variables we observed
- be possible to answer by collecting data from experiments or using secondary sources (reports of research carried out by other people).

testable question

a question that can be answered using scientific processes; it must be relevant and include the selected variables

The hypothesis

From the question, you can develop a predicted explanation for the observation. This explanation is called a hypothesis. In most investigations, the hypothesis will be the prediction of how the independent variable will affect the dependent variable. The hypothesis should be based on prior knowledge or research so that it is an educated prediction and not a random guess.

A hypothesis must:

- be a statement
- be testable
- be specific for the investigation
- link the independent and dependent variables
- be based on an educated prediction, not a random guess.

In the example of adding salt to water, the independent variable is salt being added to the water and the dependent variable is how long it takes for the water to boil. All other variables, such as the size of the container, the amount (volume) of water, how the containers are heated and how you determine if the water is boiling, need to be controlled. From this, the hypothesis is what you predict adding salt to the water will do to the time it takes to boil; for example, 'If salt is added to water, then it will take less time to boil'.



▲ FIGURE 1.4.2 Adding salt to water in a saucepan being heated on a stove

trend
the general pattern or direction of data

Writing a hypothesis

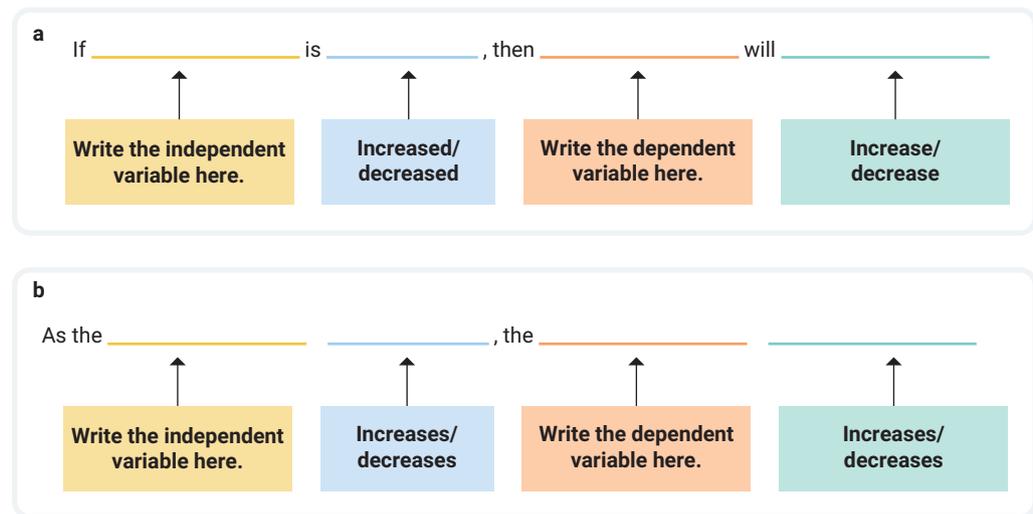
Often a hypothesis is in the form of an 'If . . . then . . .' statement, as shown in the example below and in Figure 1.4.3. A more advanced hypothesis may state how changing one factor will affect the results of another in the form of a **trend**. For example:

Question: How does the mass (amount) of salt added to water affect the time taken to boil?

Independent variable: The mass of salt added to the water

Dependent variable: The time taken for the water to boil

Hypothesis: As the mass of salt added to the water increases, the time taken for the water to boil decreases.



► **FIGURE 1.4.3**
(a) A simple method for writing a hypothesis.
(b) An alternative method for writing a hypothesis.

Predictions

prediction
the expected results

A **prediction** is the expected result for a test. Therefore, it is what you think will happen if your hypothesis is supported.

For example, the prediction for the salt-in-water experiment could be that water containing salt boils more quickly than water without salt. Or for a more advanced investigation, the prediction could be that the water with the most salt will boil the quickest.

For each of the images in Figure 1.4.4 write:

- a an observation.
- b a testable question.
- c a hypothesis.
- d a prediction.



▲ FIGURE 1.4.4

1.4 LEARNING CHECK

1 Define:

- a hypothesis.
- b prediction.

2 List the features of a hypothesis.

3 Classify each of the following as an observation, a question, a hypothesis or a prediction.

- a If the temperature increases, then the number of flies decreases.
- b Ants are covering a piece of bread with honey on it.
- c The hot water will dissolve the most sugar.
- d Will the size of a discus affect how far it is thrown?
- e As the frequency of watering increases, the rate of growth of wheat increases.
- f How does the amount of fertiliser affect the growth of my grandmother's roses?

4 State the independent and dependent variables for each of the following hypotheses.

- a As the number of days over 40°C increases, the number of flies caught in the fly trap decreases.
- b If the thickness of sticky tape increases, then the force taken to remove it increases.
- c If the lid is left off a reusable coffee cup, then the coffee will get colder faster.

5 Create a flow chart, with annotations, to show the relationship between observation, question, hypothesis and prediction.

6 Write a hypothesis about heart rate and the intensity of exercise.

7 Analyse the following hypothesis by identifying ways in which it fulfils the criteria for a hypothesis and ways in which it does not fulfil the criteria: Dogs are smarter than cats.

1.5

Planning investigations: identifying purpose and variables

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe the purpose of an investigation
- ✓ identify the variables in an investigation.



Video activity
Identifying variables

GET THINKING

You are helping your grandad make a new vegie patch. You check how much sunlight the patch gets and decide which plants to buy. Your grandad suggests you add a fertiliser to the soil. How will you choose the best fertiliser?

purpose of an investigation

the reason for conducting an investigation

aim

a statement that states the purpose of the investigation

The purpose of an investigation

The **purpose of an investigation** is the reason you research a specific question. It is important to identify the purpose at the beginning of your planning. The purpose, together with the testable question, shapes the investigation. You write the purpose of the investigation as the **aim**.

The main purpose of most investigations is to collect enough scientific evidence to test the hypothesis. For example, if you are investigating which type of paint is better to repaint the furniture in your bedroom, you would need to:

- collect information about the available types of paints
- test the paints on a small spot to see which one works and looks better
- assess each paint based on a set of criteria, such as how good the colour looks, if it matches your bedroom, and smoothness.

In this example, the purpose of the investigation is to select the best paint.

The purpose has informed the other working scientifically processes you used. This allows you to select the best paint for your bedroom furniture.



Melinda Nagy/Shutterstock.com

▲ FIGURE 1.5.1 The purpose of this investigation is to choose the best paint for bedroom furniture.

Identifying variables in an investigation

In Module 1.3, you learned about the three categories of variables:

- dependent variable: the factor you're measuring
- independent variable: the factor you're changing
- controlled variables: the factors you keep the same.

Let's use an example to learn how to identify variables in an investigation.

Sample investigation – sugar dissolving in tea

Imagine you're preparing a cup of tea. In your kitchen, there are three types of sugar: raw, caster and brown sugar (Figure 1.5.2). You're not sure which sugar would dissolve the most to sweeten your tea. So, you decide to do an investigation.



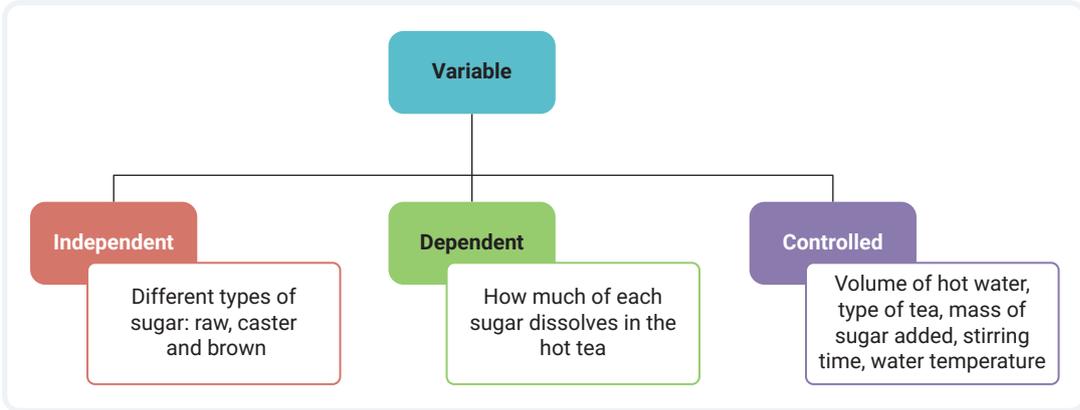
Kitamin/Shutterstock.com

▲ FIGURE 1.5.2 Three types of sugar: raw, caster and brown

Before you plan your procedure, you need to determine the:

- 1 purpose of your investigation: to test which sugar dissolves the most in a cup of tea
- 2 variables in your investigation.

The variables for this investigation are shown in Figure 1.5.3.



▲ FIGURE 1.5.3 Variables identified in the investigation

1.5 LEARNING CHECK

- 1 **Describe** the purpose of an investigation.
- 2 Suzie observed different types of bees visiting the red roses in her garden, so she decided to do an investigation. **Write** the purpose of a possible investigation Suzie could undertake.
- 3 Marco and Angela were testing different fertilisers to grow lettuce. **Create** a table to **identify** the dependent, independent and controlled variables in their experiment.

1.6 Planning investigations: methods

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define fair test, valid investigation, procedure and method
- ✓ describe how to test a hypothesis to gain valid results
- ✓ describe how to write a repeatable method
- ✓ describe different methods used by scientists.



Video activity
Fair testing

GET THINKING

A cooking recipe is a procedure that you follow. Discuss the following questions with a partner. As you work through this module, reflect on your answers and consider how they also apply to a scientific investigation.

- 1 What is the benefit of having a recipe while cooking?
- 2 Describe the outcome if everyone follows the same recipe.
- 3 What things do you need in a recipe to ensure your cooking is successful?

Planning a fair test

valid investigation

an experiment that tests the hypothesis

control test

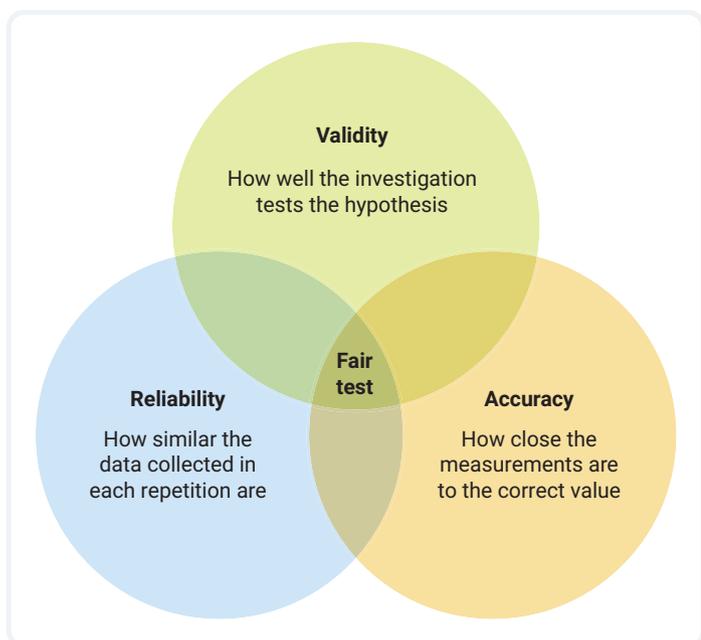
a test in an investigation in which nothing is changed; often just called the control

reliability

how similar the results of the same experiment are

Any scientific investigation must be a fair test so that it is clear what has led to the results (Figure 1.6.1). To know which variable has caused the changes in the results, it is important to carefully plan a test that changes only the independent variable, and controls the others. This means that you are conducting a **valid investigation** because it will provide data that tests the hypothesis.

In some investigations, it is important to include a test in which nothing is changed. This is called the **control test** (often just called the control) and is used as a baseline to compare other data against. The control does not include the independent variable that you are changing. In the salt and water example in Module 1.4, the control would be water without any salt.



▲ FIGURE 1.6.1 The factors that influence a fair test

You should also collect multiple sets of data so that you can be confident that the result was not due to luck or accident. Wherever possible, conduct multiple trials, and calculate an average of the data. Conducting multiple trials within one experiment increases the **reliability** of the experiment. Other ways to increase reliability are to complete the same experiment multiple times and for other people to conduct the same experiment.

The procedure

When planning an investigation, you write the steps that you expect to take in the **procedure**. You need to consider the following points:

- What is the purpose of your investigation?
- What are the independent, dependent and controlled variables in your investigation?
- What measuring equipment will you need? For example, you would not use a measuring cylinder to measure temperature.
- What equipment will give you accurate measurements? For example, to measure the volume of a liquid accurately, you would use a measuring cylinder, not a beaker.
- How will you test an adequate number of variations of the independent variable? For example, you could test the time for water to boil if 5 g, 10 g and 15 g of salt was added.
- How will you conduct sufficient trials for each test so that you can be sure that your data is reliable? For example, you could repeat each test three times and then average the data.

A good procedure:

- uses numbered steps
- has specific details with units of measurement, such as ‘measure 10 mL of water using a measuring cylinder’
- has simple commands written in the present tense, such as ‘stir for 5 minutes’
- outlines how the independent variable changes
- includes the number of repetitions needed
- explains how data should be recorded and analysed
- is **ethical**.

The method

The **method** is a set of steps describing what you did to carry out your investigation. During an investigation, scientists often need to alter the procedure to ensure the investigation is a fair test and relevant to the testable question. Therefore, the method is a more accurate account of how the data was collected than the original procedure.

A good method will:

- be clear and concise
- be written in the third person and past tense
- often be supported with a clear, labelled diagram or photo of the experimental set-up.

procedure

a set of instructions to follow; written in the present tense

ethical

morally right, fair

method

the steps that were taken during a scientific investigation; written in past tense

Table 1.6.1 shows the procedure and method for part of an investigation testing whether adding salt to water changes the time it takes for the water to boil.

▼ **TABLE 1.6.1** Part of the procedure and method for the investigation of whether salt affects the time it takes water to boil

	Procedure	Method
1	Measure 100 mL of water and pour it into a beaker.	100 mL of water was measured with a measuring cylinder and poured into a 250 mL beaker.
2	Light the Bunsen burner and open the air hole to change the flame to a blue flame.	The Bunsen burner was lit and then the air hole was opened to change the flame to a blue flame.
3	Use tongs to place the beaker on a gauze mat on a tripod stand over a Bunsen burner.	The beaker was lifted using tongs and placed on a gauze mat on a tripod stand over a Bunsen burner.
4	Start the stopwatch as soon as the beaker is over the Bunsen burner.	The stopwatch was started as soon as the beaker was over the Bunsen burner.
5	Stop the stopwatch when the water is boiling.	The stopwatch was stopped when the water was boiling.
6	Repeat steps 1–5 four times.	Steps 1–5 were repeated four times.

Techniques used to collect data

Scientists collect data using different techniques. For example:

- A survey could collect data about people’s opinions.
- Field studies could collect data about the environment.
- Sampling could collect data about wildlife.
- Laboratory tests could collect data about chemicals.
- Observations could collect data about behaviour.
- Clinical trials could collect data about new drugs.

The technique a scientist chooses will depend on the type of data they want to collect and the question they want to answer. You will learn more about types of data in Module 1.9.



▲ **FIGURE 1.6.2** One way scientists collect data is in a field study in the environment.

☆ ACTIVITY

How accurate is your method?

Aim

To work in groups of three to test the accuracy of each other’s method

Materials and equipment

- paper
- coloured pens or pencils
- ruler
- 20 mL measuring cylinder
- 100 mL beaker
- food dye

- stirring rod
- items in a pencil case
- device to record a video (if possible)

Procedure

- 1 Allocate the following roles in the group.
 - Person A completes a task initially.
 - Person B writes the method.
 - Person C completes the task a second time.
- 2 Person C moves to an area where they cannot see what persons A and B are doing.
- 3 Person A completes one of the following tasks. If possible, record them doing this on a video.
 - a Draw a simple shape with different coloured pens on a piece of paper.
 - b Pour exactly 20 mL of water and 3 drops of food dye into a 100 mL beaker and then stir the solution.
 - c Arrange the items from a pencil case into a certain design.
- 4 Person B writes a method for what person A did without talking to person A.
- 5 Put the finished product from step 3 out of sight.
- 6 Person C returns to the group and, using only the method, does the same task as person A.
- 7 Compare the finished products from persons A and C. How accurate was person B's method?
- 8 Swap roles and repeat the process so that everyone takes each role.

Analysis

- 1 What characteristics did the method need to have for person C to closely recreate person A's product?
- 2 What challenges were there in writing an accurate method?

1.6 LEARNING CHECK

- 1 **List** four features of a procedure for a fair test.
- 2 **Explain** why a fair test changes only one variable.
- 3 **Explain** why it is important that a test is conducted more than once.
- 4 **Write** a procedure for brushing your teeth.
- 5 **Explain** why it is important for a procedure to be detailed.
- 6 Use the following brief procedure to **write** a method for testing the bounciness of different balls.
 - 1 Drop the ball from 1 m high.
 - 2 Count how many times the ball bounces before it stops.
 - 3 Repeat this for other balls.
 - 4 Test all balls three times.
- 7 **Explain** the differences between a method and a procedure.

1.7

Planning investigations: safety

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ state common safety rules for a science laboratory
- ✓ classify actions as either safe or unsafe for a science laboratory
- ✓ explain the purpose of each safety rule in a science laboratory
- ✓ justify why certain actions are unsafe in a science laboratory
- ✓ list common safety equipment for a science laboratory.



Video activity
Science safety

GET THINKING

Safety is always the highest priority in our homes, schools, sporting groups, roads, shops and playgrounds, as well as in science laboratories. Choose one aspect of your everyday life and reflect on the rules that are in place to help keep you safe.

- 1 List five rules that help keep you safe.
- 2 Are there any signs that remind us of the safety rules? If there are, draw one and describe how it helps keep people safe.
- 3 Suggest what would happen if there were no safety rules.

Hazards in the laboratory

In a science laboratory, there are objects and activities that could be dangerous. These are called **hazards**. For this reason, there are specific safety rules and equipment in a science laboratory.

hazard

something that has the potential to harm

Safety rules

Each science laboratory will have its own set of rules. However, there are some rules that are common to all science laboratories.



▲ FIGURE 1.71 Wear safety glasses, lab coat and gloves when doing experiments in a science laboratory.

1 *Follow your teacher's instructions and classroom rules.*

This is so that you do things safely and in a scientific way.

2 *Do not enter the laboratory without your teacher.*

Your teacher can give you instructions to ensure that you are not exposed to unnecessary risks in the science laboratory.

3 *Wear safety glasses, lab coat (or apron), gloves and enclosed shoes.*

This protects your eyes and skin from chemicals that could cause damage.

4 *Tie long hair back and secure loose clothing.*

This stops your hair and clothing catching fire or falling into chemicals.

5 *Do not eat or drink in the laboratory.*

Food and liquids can be contaminated in the laboratory and therefore should never be eaten there.

6 *Do not run in the laboratory.*

When you run, you are more likely to trip and fall, or knock someone or something.

7 *Do not smell or taste anything in a laboratory.*

The chemicals in a laboratory can be dangerous to smell or ingest.

8 *Ensure equipment cannot fall off the bench.*

It is easy for science equipment to fall or be knocked off the bench. This can cause the contents of the container to spill and lead to broken glass, which can cut people.

9 *Report spills and breaks.*

Your teacher needs to know about any spills or breaks. They will check the spill or breakage and direct you so that it is cleaned up appropriately. Any broken glass should be put into a special glass bin.

10 *Never leave a lit Bunsen burner unattended.*

A lit Bunsen burner can cause fires, or a gas leak if the flame goes out.

11 *Be careful with hot equipment and chemicals.*

Hot equipment and chemicals can cause burns. To protect against burns, use tongs to hold hot equipment and make sure hot chemicals don't splash onto people.

12 *Always put lids back on bottles.*

Bottles without lids can easily lead to chemical spills. Keep lids on to reduce this risk.



▲ **FIGURE 1.7.2** Ensure that equipment doesn't fall or get knocked over.



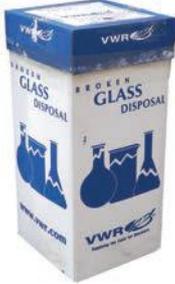
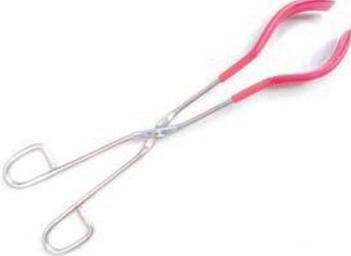
▲ **FIGURE 1.7.3** Never leave a lit Bunsen burner unattended.



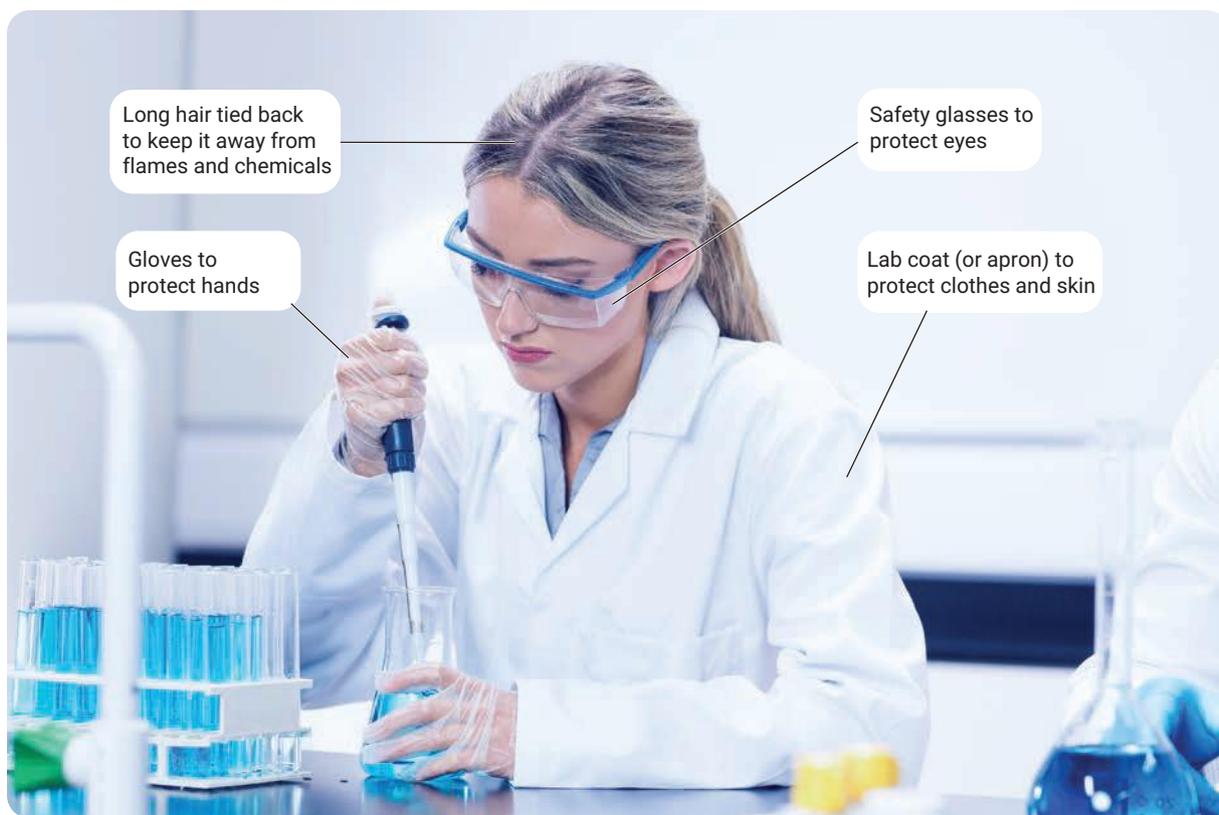
▲ **FIGURE 1.7.4** Always replace the lids on bottles of chemicals.

Safety equipment

Science laboratories contain a lot of equipment to keep you safe, including personal protective equipment (PPE) that you will wear. Figures 1.7.5 and 1.7.6 summarise some of the equipment that you will use.

<p>Shower to rinse, dilute and remove chemical spills on people</p> 	<p>Eye wash to rinse chemicals from eyes</p> 	<p>First aid kit to treat small cuts and burns</p> 
<p>Availability of water to dilute and rinse chemicals</p> 	<p>Fire extinguisher to put out any fires</p> 	<p>Fire blanket to smother fires</p> 
<p>Switch to turn off the gas in the case of a gas leak or fire</p> 	<p>Switch to turn off the electricity in the room</p> 	<p>Bin for any broken glass</p> 
<p>Spill kit to neutralise, absorb and contain any chemical spills</p> 	<p>Fume hood to remove dangerous gases during experiments</p> 	<p>Tongs to handle hot equipment</p> 

▲ FIGURE 1.7.5 Some of the safety equipment used in a science laboratory



▲ FIGURE 1.7.6 Personal protective equipment (PPE) is worn to keep you safe in the laboratory.

1.7 LEARNING CHECK

- 1 **List** five pieces of equipment that would be used if a beaker containing chemicals was spilled in the science laboratory.
- 2 **Describe** what might happen if someone ate their lunch in the science laboratory.
- 3 **Explain** why it is important to tie long hair back when working in a science laboratory.
- 4 Organise yourself into groups of three or four students. Use a sheet of paper for the group. Without discussing it, pass the paper around the group so that each person can **write** down a safety rule. How many rules can your group remember?
- 5 Why are the rules in the science laboratory different from those in your maths classroom?
- 6 **Create** an advertisement to promote one safety rule for the science laboratory. You may do this as a poster, video or a podcast.
- 7 Use three A4 sheets of paper to make 30 cards by cutting each in half lengthwise and then each half into fifths. For each piece of safety equipment in the science laboratory, write the name on one card and draw a diagram of it on another. Turn the cards face down on the table and use them to play a game of Memory.

1.8 Conducting investigations: equipment

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ identify common laboratory science equipment, including Bunsen burner, beaker, conical flask, test tube, tongs, test-tube rack, retort stand, tripod stand, gauze mat, stirring rod and spatula
- ✓ state the function of each item of common science laboratory equipment
- ✓ describe how to use common science laboratory equipment.



Interactive resource
Match: Science equipment

Worksheet
Drawing science equipment

GET THINKING

What equipment do you already know about? Use the interactive resources on Nelson MindTap to play games to match the names to pictures of different pieces of equipment that are used in the science laboratory. How many did you already know? Did you remember more as you played the games?

Specialised science equipment

Scientists use a lot of specialised **equipment**. In most cases, the equipment is designed to perform a particular task and so it is called the **apparatus**. Science requires accurate, consistent measurements that other scientists can repeat. Therefore, it is important to know the name of the equipment that you have used for your measurements and how to use it safely and accurately. In Module 1.7, you learned about equipment that keeps you safe, and in Chapter 3, you will learn about equipment used to measure data. In this module, you will learn about other equipment used in science.

equipment
tools used to perform a task

apparatus
equipment designed or set up together for a particular use

Equipment used to hold liquids

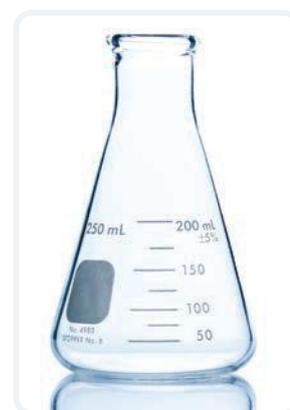
Different types of containers, including test tubes, beakers and conical flasks, are used to hold liquids depending on their volume and the type of experiment. Test tubes are useful for small volumes, whereas beakers and conical flasks are used for larger volumes. Although beakers and conical flasks have volume measurements on their sides, these are not accurate. Therefore, beakers and conical flasks should not be used as accurate measuring instruments.



broukoid/Shutterstock.com



kwanchai.c/Shutterstock.com



kwanchai.c/Shutterstock.com

▲ FIGURE 1.8.1 Test tubes, beakers and conical flasks are used for holding liquids.

Equipment used for heating

In some science classes, you will heat substances. You can use either an electric hot plate (Figure 1.8.2) or a Bunsen burner (Figure 1.8.3).

A Bunsen burner sits on a heatproof mat to protect the bench. A tripod stand with gauze mat supports flat-bottomed flasks such as beakers above the flame.

Equipment to help you see small objects

Many things in science are too small to be seen with the naked eye. Magnifying glasses (Figure 1.8.4) or microscopes (Figure 1.8.5) **magnify** objects so that you can see them in detail. The equipment that you choose will depend on how much you need to magnify the object. A microscope will magnify the object much more than a magnifying glass.



Thx4Stock/Shutterstock.com

▲ FIGURE 1.8.4 Magnifying glasses can let you see small objects, such as parts of a plant, more clearly than with the naked eye.



Inside Creative House/Shutterstock.com

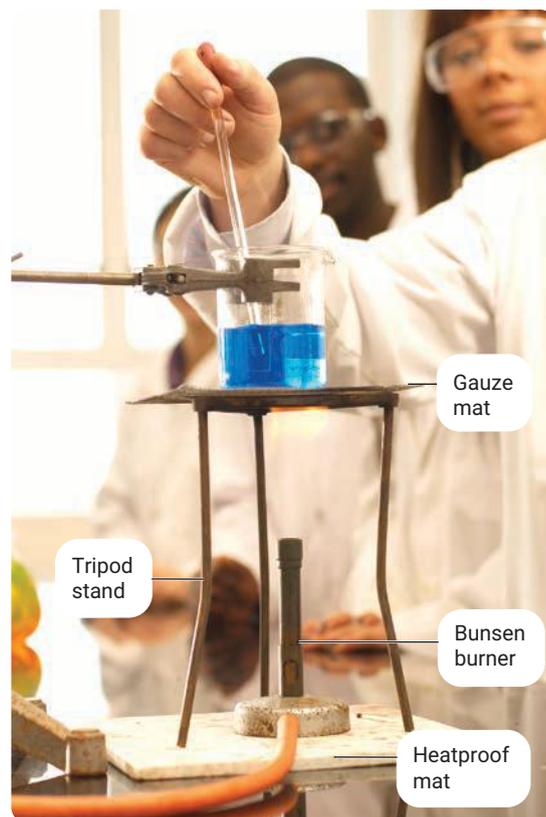
▲ FIGURE 1.8.5 Light microscopes reveal details of small objects.



Rabbitmindphoto/Shutterstock.com

1.8

▲ FIGURE 1.8.2 An electric hot plate is used to heat substances.



iStock.com/Peter Muller

▲ FIGURE 1.8.3 A Bunsen burner with a heatproof mat, tripod stand and gauze mat. This is called the heating apparatus.

magnify
to make something appear larger

Equipment used for holding

There are different-shaped tongs to safely hold items such as test tubes or beakers, especially when they are hot.

Tweezers, or forceps, are used to pick up small things without touching them.

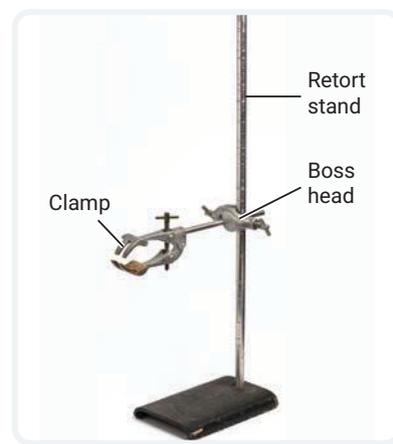
Test-tube racks hold test tubes (Figure 1.8.6). They are particularly useful because test tubes have rounded bottoms and so do not stand up on their own. Most test-tube racks can hold multiple test tubes, allowing several tests to be done at the same time.

A retort stand, with a boss head and clamp (Figure 1.8.7), holds equipment such as test tubes. It can be used to keep equipment in a particular position, such as above a Bunsen burner.



kai keisuke/Shutterstock.com

▲ FIGURE 1.8.6 Test-tube racks are used to hold test tubes for experiments.



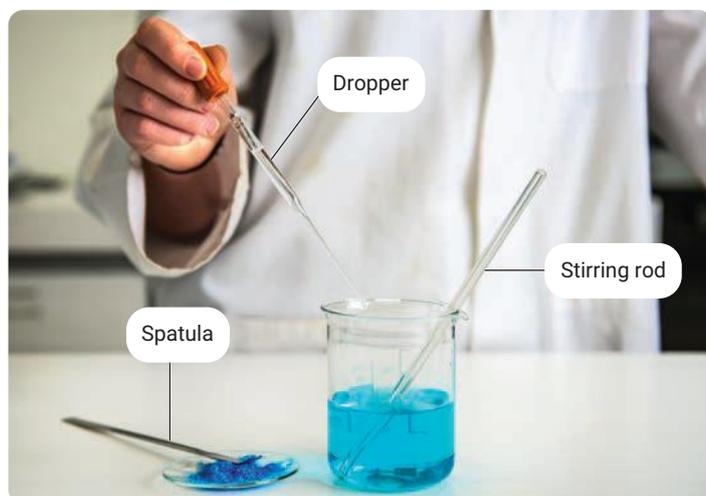
David Hare / Alamy Stock Photo

▲ FIGURE 1.8.7 A retort stand, boss head and clamp

Other equipment

Some other pieces of equipment that you will use in the science laboratory are a:

- stirring rod – a thin glass or plastic rod used to mix substances
- spatula – a shallow metal or plastic spoon used to transfer powders
- dropper – a small plastic or glass tube used to collect and transfer small volumes of liquid.



Mark Fergus Photography

▲ FIGURE 1.8.8 A stirring rod, spatula and dropper being used in an experiment

1.8 LEARNING CHECK

1 **State** the names and uses of the following pieces of equipment.



2 **Draw** a labelled diagram to show a beaker sitting on a gauze mat on a tripod stand and being heated by a Bunsen burner sitting on a heatproof mat.

3 **List** two pieces of equipment that could be used to:

- a** hold water.
- b** pick up something.
- c** see something that is very small.
- d** heat something.

4 **Describe** the equipment you would use to put some powder in a test tube and heat it safely over a flame.

5 **State** a similarity and a difference between the two items in each of the following pairs:

- a** a test tube and a beaker.
- b** a microscope and a magnifying glass.
- c** a spatula and a dropper.
- d** a retort stand and tongs.

1.9

Conducting investigations: recording data

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe the components of an effective table
- ✓ organise data in an effective table
- ✓ describe the importance of units of measurement
- ✓ compare qualitative and quantitative data.



Interactive resource

Match: Data and results

Drag and drop: Types of data

Worksheet

Converting units of measurement

GET THINKING

The information about your classes for each day is organised into a timetable.

- 1 Describe how the information is arranged in your timetable.
- 2 Explain the benefits of having the information arranged in a timetable.
- 3 Predict what would happen if you didn't have a timetable.

Types of data

When scientists conduct an investigation, they make observations and measurements, called **data**. The processed and analysed information gained from this data is the **results** of the investigation. The results are the evidence that will support or disprove the testable question.

As you learned in Module 1.2, there are two types of data: qualitative data and quantitative data (Table 1.9.1).

▼ TABLE 1.9.1. The differences between qualitative and quantitative data

Qualitative data	Quantitative data
<ul style="list-style-type: none"> • Describes what you see and observe. It does not measure anything. • Includes things such as colours, textures, smells, tastes, appearances and perceptions. 	<ul style="list-style-type: none"> • Means numbers and things you can count or measure. • Can be represented in tables and graphs.

Units of measurement

In science, you must use and record the appropriate unit of measurement when you collect data. You should also collect data using the same unit of measurement throughout your investigation, to avoid confusion. For example, if you are measuring height, choose one unit for all measurements, such as centimetres. This will help you to avoid errors when you process the data. If different units of measurement are used, you must convert all of them to the same units before you process your data.

Organising data into tables

It is important to organise and evaluate the data correctly so that valid conclusions are made. The most common, effective way to organise data is in a table, with **rows** and **columns**. This makes it easier to identify trends in the results and any **anomalies** in the data. Figure 1.9.1 shows the features of an effective table.

data

the numbers or observations collected during an experiment; information gathered for a scientific inquiry

results

the information gained from an experiment

DATA SCIENCE



See **Modules 2.2 and 2.3** for more about quantitative and qualitative data.

row

a horizontal division in a table

column

a vertical division in a table

anomaly

something that deviates from the standard

TABLE 1. The time taken for 100 mL of water to boil with and without added salt

An informative title that indicates the independent and dependent variables

Independent variable in the first column

Dependent variable in the other columns

Headings, including the units

Average (mean) of the data

Organised into neat columns and rows

Whether salt was added or not	Time taken for water to boil (s)			
	Trial 1	Trial 2	Trial 3	Average
No salt	165	180	172	172.3
Salt	235	228	240	234.3

Results

Data

▲ FIGURE 1.9.1 Features of an effective table

Using data from secondary sources

In science, we use a range of **secondary sources** (reports of scientific work by other people) that:

- give information or background about the question we are testing or researching
- provide information about techniques we could use in our procedure
- let us compare our data with data from other researchers.

Secondary sources of data often come from other scientists who have performed the investigation or researched the topic. This is called **scientific literature**, and it is available in libraries and on the internet. It is important to **cite** (provide full publication details of) the sources when we use other people's data or publications (secondary sources).

Not all secondary sources of information are of the same quality. You will learn how to check the validity and reliability of secondary sources and data in Modules 2.5 and 2.6.

secondary source
a publication, information or data that has been written or collected by another person

scientific literature
secondary sources of data from scientists; used as references in investigations

cite
to reference or give credit to a secondary source of data or information

1.9 LEARNING CHECK

- 1 **List** the features of an effective table.
- 2 **Explain** why an effective table for results is beneficial during an investigation.
- 3 **Explain** why it's important to use the same units of measurement when collecting data.
- 4 **Compare** and **contrast** qualitative and quantitative data and give an example of each.
- 5 During an investigation, Ajang measured the height of grass that was planted in different media (sand, potting mix, compost, gravel and clay). **Construct** a table for Ajang to record his results in.

1.10 Processing data and information

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ select the correct graph to visualise types of data
- ✓ explain why certain graphs are appropriate for different types of data.



Video

Science skills in a minute: Organising data

Science skills resource

Science skills in practice: Organising and representing data

GET THINKING

Think about the receipt you get when you buy groceries from the supermarket. How can you organise the data in the receipt to see how much money you spend on different items? How could you process that information as scientific data?



▲ FIGURE 1.10.1

▼ TABLE 1.10.1 Heights of meerkats

Meerkat	Height (cm)
Alex	63
Brianna	58
Cam	72
Daniel	80
Dora	63
Ellie	50
Huang	68
Milly	55

Processing data

You can present scientific information in different ways, such as text, diagrams, tables, graphs, databases, talks and videos. In Module 1.9 you learned how to create tables to record the data you collect. In this module, you are going to learn how to process that data. This will make it easier for you to analyse the data later, so you can use it as evidence to support your testable question.

To show how to process data, we'll explain the steps using an example.

Observations, testable questions and data collection

You are visiting the local zoo and you observe that there are differences in the heights of meerkats when they stand up. You decide to investigate the question: are the female meerkats taller than the males? You contact the zoo for approval to run the investigation. The zookeeper tells you that each meerkat has a tag with its name and helps you to measure the height of each one. The data is recorded in a table (Table 1.10.1).

Organising the data

The next step is to classify the data in the table into categories. In this example, you use the categories of female and male. You can put the data into categories in an Excel spreadsheet or manually into a table (Table 1.10.2).

▼ TABLE 1.10.2 Height of meerkats, separated into males and females

Female meerkat name	Height (cm)	Male meerkat name	Height (cm)
Brianna	58	Alex	63
Dora	63	Cam	72
Ellie	50	Daniel	80
Milly	55	Huang	68

Finding an average

Sometimes, you will collect a large amount of quantitative data in an investigation and will want to find an average value, or **mean**. To find the mean, you:

- add up all the data for one variable to get a total – in this case, add the heights of each group of meerkats. For example, $58 + 63 + 50 + 55 = 226$.
- divide the total by the number of data points – in this case, the total number of female or male meerkats. For example, $226 \div 4 = 56.5$ cm

You will then have the average height of each group to compare. In this case, the average height of the female meerkats is 56.5 cm, while the average height of male meerkats is 70.75 cm.

mean

the calculated 'central' value of a set of numbers; an average

DATA SCIENCE



See **Module 2.7** to learn how to calculate range and median.

Types of graphs

You can represent data visually in a graph. This makes it easier to see any pattern or trend in the data.

The type of graph you use depends on the type of data you record. **Discrete data** can only have certain values, whereas **continuous data** can have an infinite number of values between whole numbers. For example, the number of meerkats in the zoo is discrete data because you cannot have half a meerkat. By contrast, meerkat height is continuous data because it is possible to have a range of height values, not just whole numbers.

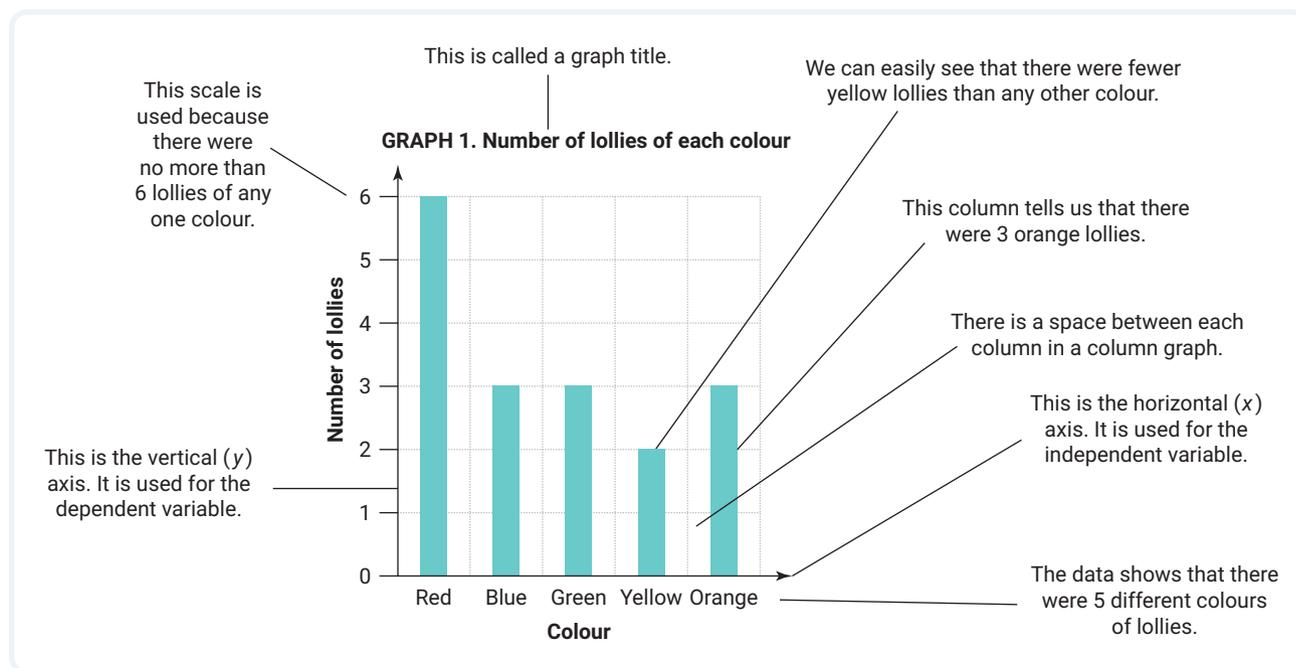
Two of the most common types of graphs in science are column graphs and line graphs. Column graphs, such as the one in Figure 1.10.2, are best for representing discrete data and qualitative data.

discrete data

data where there is only a limited number of possible values

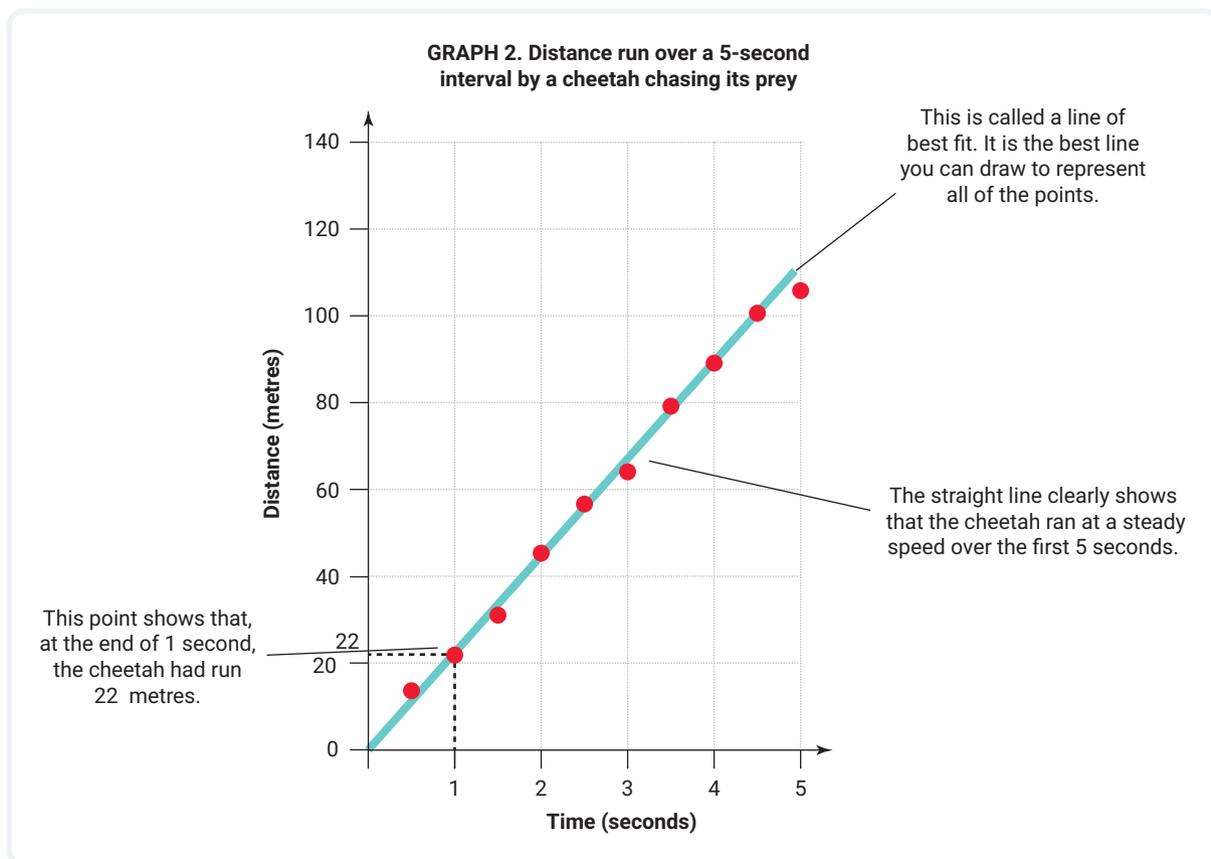
continuous data

data from measurements that may include whole numbers and any value between them



▲ FIGURE 1.10.2 Use a column graph for discrete data and qualitative data.

Line graphs, such as the one in Figure 1.10.3, are used when both variables are continuous data.



▲ FIGURE 1.10.3 Use a line graph for continuous data.

Drawing graphs

There are rules you need to follow when drawing all graphs.

- Use an informative title that includes the independent and dependent variables.
- Clearly label the horizontal and vertical axes.
- Graph the independent variable on the x-axis (the horizontal axis).
- Graph the dependent variable on the y-axis (the vertical axis).
- Label the variable on each axis.
- Use units in brackets (if appropriate) with the axis label.
- Use a scale on each axis that goes up in regular increments if the data is numerical.
- In most cases, graph the average of the data.
- Use a key to identify data if there is more than one set of data graphed on one set of axes.
- Add a **line of best fit** wherever possible for line graphs.
- Use the maximum area of the graph paper (within reason) when you draw by hand.

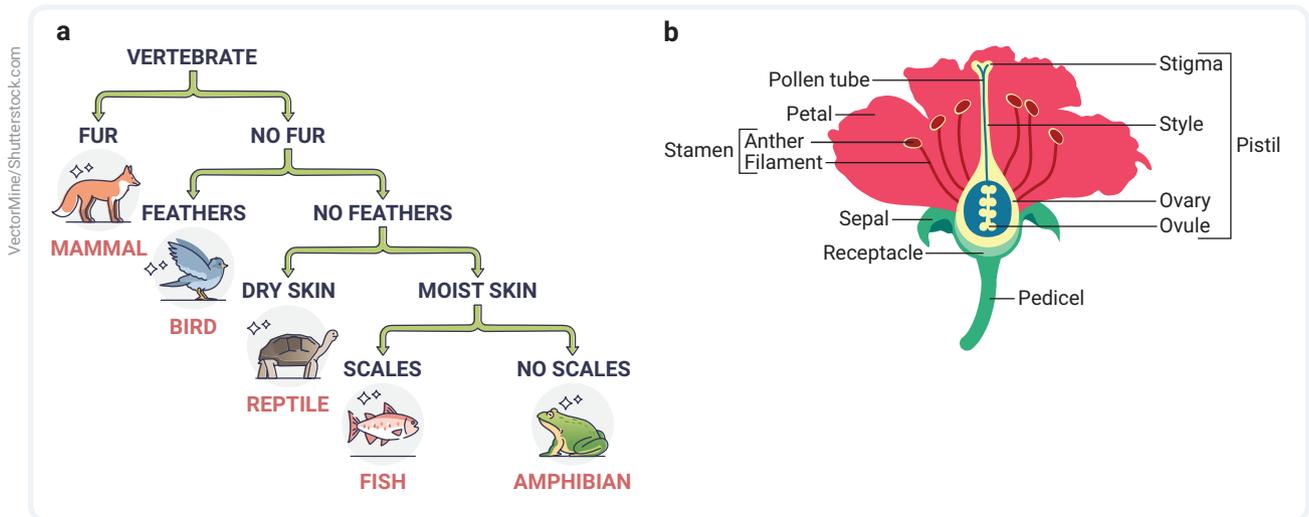
line of best fit

the line that best represents the trend of a set of data points

Other ways to present data

We can organise and present scientific data in many ways, such as using keys, models, diagrams and infographics.

For example, we use keys to identify living things based on their physical characteristics (Figure 1.10.4a). We use models and diagrams to represent complex scientific concepts (Figure 1.10.4b).



▲ FIGURE 1.10.4 (a) Keys and (b) diagrams are some of the ways you can present scientific data.

1.10 LEARNING CHECK

1 Define:

- a continuous data
- b discrete data.

2 Sue is counting how many moons are around each planet in the solar system. **Identify** what type of graph is suitable for this type of data.

3 What type of graph should you use for:

- a the length of a day at different times of year?
- b the volume of carbon dioxide released from different types of plants?
- c whether people prefer coffee, tea or hot chocolate?

4 **Explain** why and when scientists would use different types of formats to organise and present their data.

1.11 Analysing data and information

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define accuracy, reliability and validity
- ✓ evaluate data for accuracy, reliability and repeatability
- ✓ identify trends, patterns and relationships in data
- ✓ evaluate an investigation for validity and reproducibility
- ✓ write a valid conclusion.



Interactive resource

Crossword:
Scientific processes

GET THINKING

The librarian at your school wants to know how many books were borrowed during the year in various categories, such as science, history and sport. How will she need to analyse the data?

Analysing data in graphs to identify patterns and trends

pattern

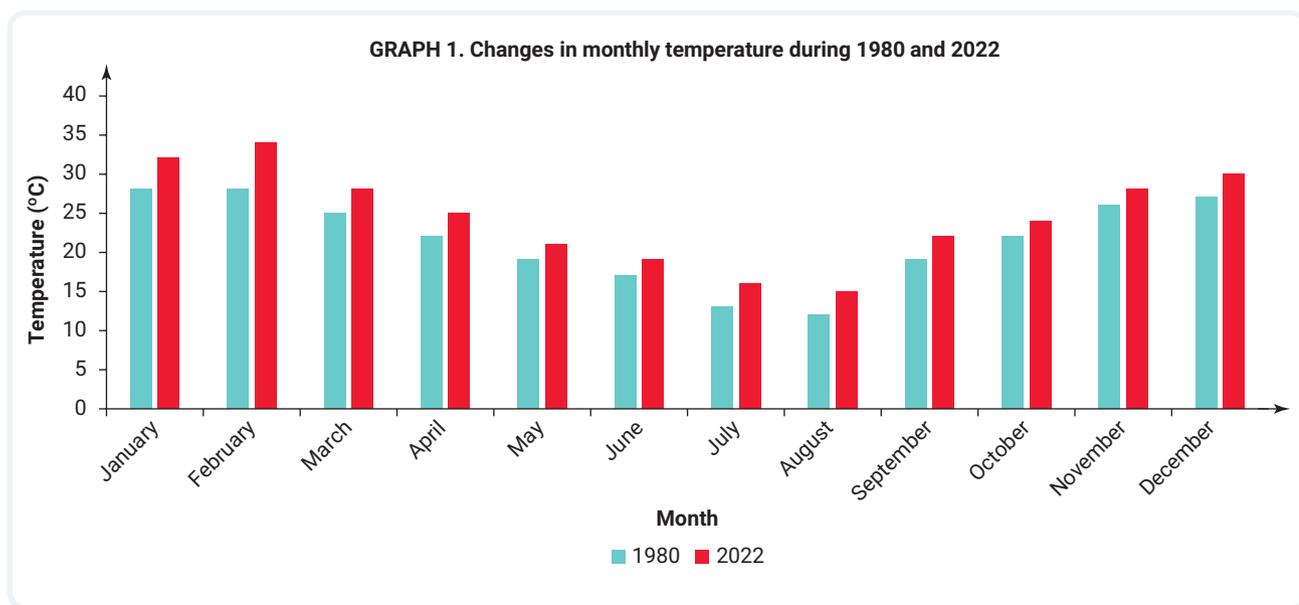
data that repeats in a predictable manner

analysis

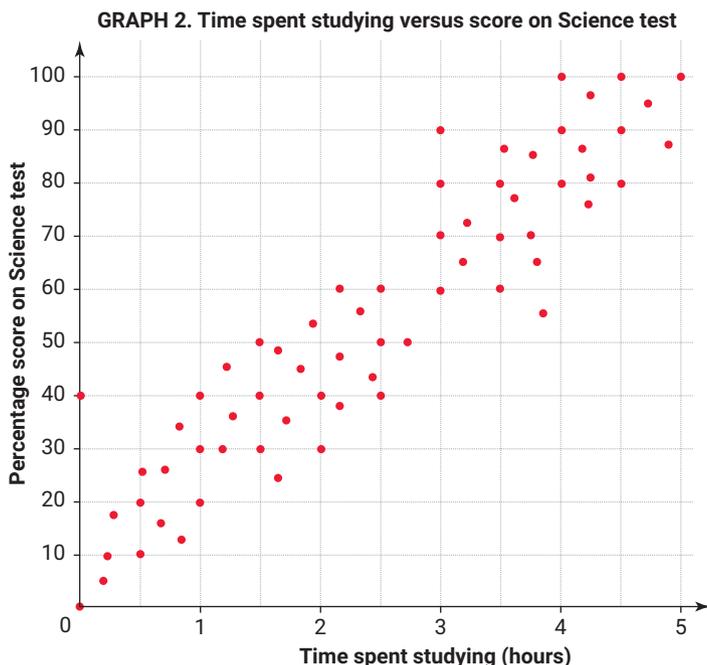
the careful study of data to look for patterns and trends

Once you have organised the data, you need to analyse it for patterns and trends. A **pattern** is when the data repeats in a predictable way. For example, if you made an **analysis** of the increase and decrease of average temperatures each year, it would reveal a pattern.

A trend, or relationship, between the variables happens when the dependent variable consistently changes in a certain way. For example, there is a trend between the mass of an object and the energy needed to lift it: the heavier the object, the more energy is needed to lift it. Figures 1.11.1 and 1.11.2 show examples of different trends between variables.



▲ FIGURE 1.11.1 This graph shows a pattern of average temperatures in Australia in 1980 and 2022. In both years, you can see there are higher average temperatures in summer and lower average temperatures in winter.



▲ **FIGURE 1.11.2** This graph shows a trend of increasing score on a Science test as the number of hours spent studying increases.

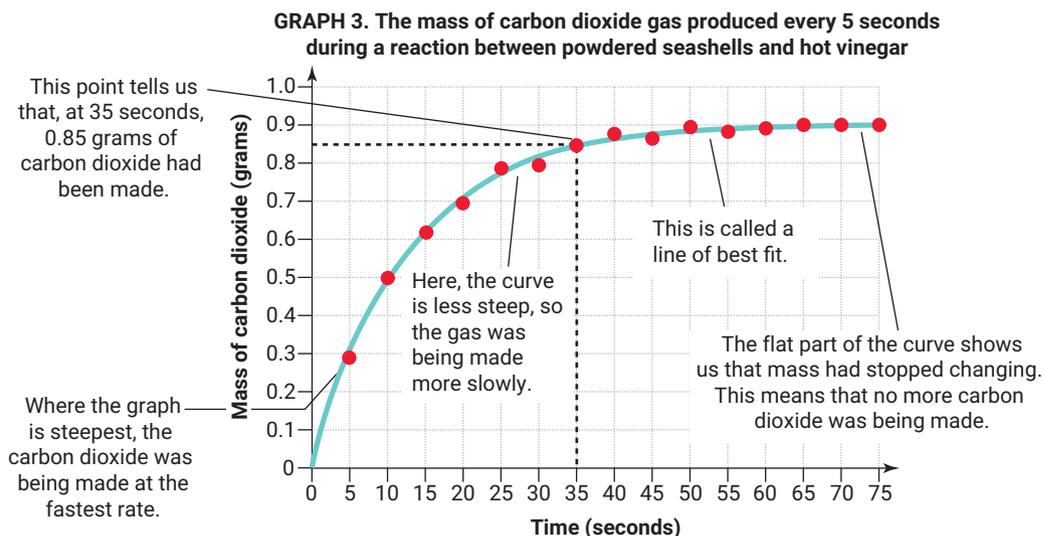
If the trend is the same as the predicted trend, then the results are evidence that supports the hypothesis.

Another way we can analyse graphs is by looking at the individual points in the graph and adding a line of best fit. For example, the graph in Figure 1.11.3 shows the mass of carbon dioxide produced over time in an experiment. Using the line of best fit, we can see that the rate of carbon dioxide production is not consistent over time. We can also use the individual data points to obtain precise information at a given time, which helps us make inferences.

DATA SCIENCE



See **Modules 2.7 and 2.8** to learn more about analysing data in graphs.



▲ **FIGURE 1.11.3** How to interpret a curved line graph

Evaluation

The next scientific process is to evaluate the data and the method. Evaluation allows scientists to assess the quality of their conclusions. To evaluate an investigation thoroughly, it needs to be repeated in exactly the same way by the same person and by others. This provides multiple independent results that can be compared.

Table 1.11.1 summarises the factors that scientists discuss in an evaluation.

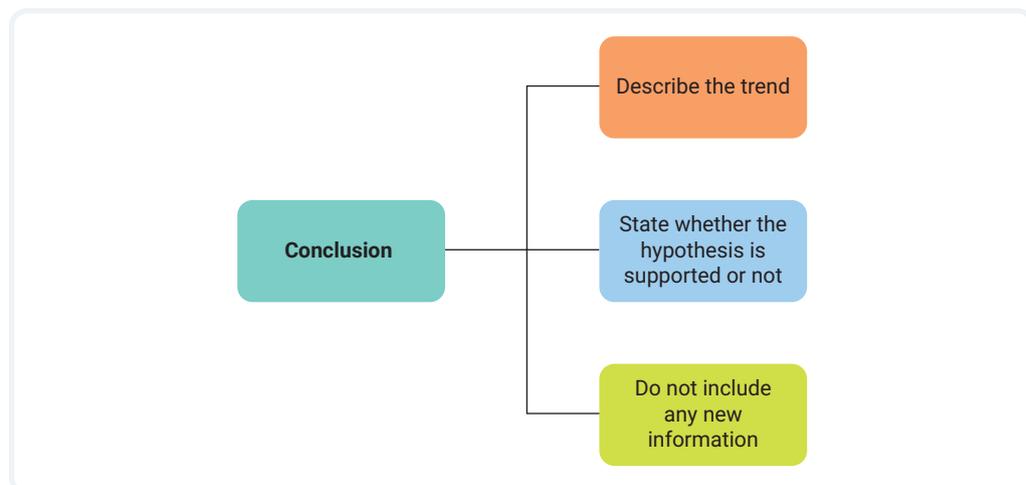
▼ TABLE 1.11.1 Factors to consider when evaluating a scientific investigation

Characteristic	Definition	Factors to consider in the evaluation of the investigation
Accuracy of the data how close a measurement is to the correct value	How close a measurement is to the true value	<ul style="list-style-type: none"> • Choose the correct equipment • Choose the most appropriate size of equipment • Use the equipment correctly • Use consistent, correct units for measurements
Reliability of the data	How similar data is when collected from repeated experiments	<ul style="list-style-type: none"> • Can be identified only if multiple trials or tests are conducted • Is increased by a clear, detailed method that is used each time
Validity of the method the extent to which an investigation tests a hypothesis	How well an investigation tests the hypothesis	<ul style="list-style-type: none"> • The independent variable is changed • The dependent variable is measured • All other variables are controlled

You must evaluate the data before you can decide if you have evidence to support or reject the hypothesis and testable question. You can gather more information from secondary sources to back up your findings.

The conclusion

The conclusion is a clear statement of what you found in the investigation and whether or not it supported the hypothesis (Figure 1.11.4). You should not introduce any new information in the conclusion; it should simply summarise your findings.



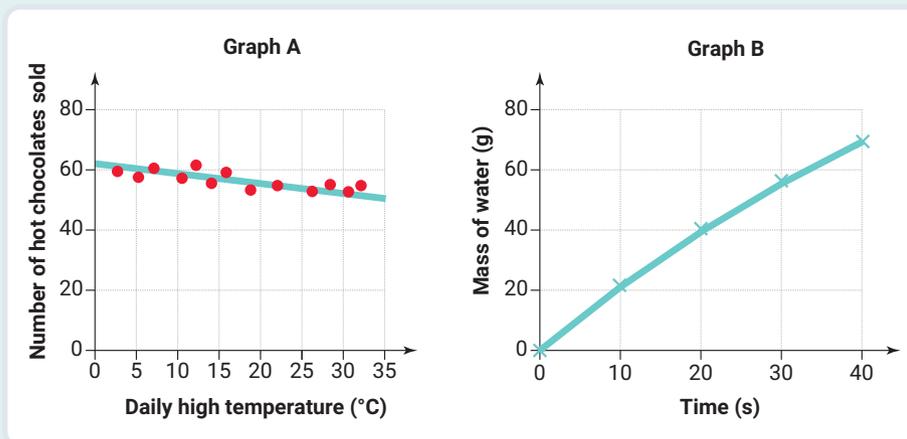
▲ FIGURE 1.11.4 A summary of what to include in a conclusion

1.11 LEARNING CHECK

- 1 The table below shows the results of an experiment investigating the time taken for bleach to remove the colour from dye at different temperatures.

Temperature (°C)	Time taken for the colour of dye to be removed (seconds)			
	Trial 1	Trial 2	Trial 3	Average
0	240	235	242	
20	189	185	186	
50	80	75	78	
70	20	22	21	

- State the independent variable and the dependent variable.
 - Write a possible hypothesis for the investigation.
 - Calculate the average of the times at each temperature.
 - Graph the average time against temperature.
 - Describe the trend between the temperature of the bleach and the time for the dye to lose its colour.
- 2 Describe the trend shown in each of the following graphs.



- 3 Define:
- accuracy.
 - reliability.
 - validity.
- 4 List two things that would reduce the accuracy of an investigation of the force required to tear paper of different thicknesses.
- 5 Explain how a clear method allows you to collect reliable data in an investigation.
- 6 Before a new pharmaceutical drug is released to the public, it must undergo several tests. Discuss why it is important that reproducible results are obtained before the drug is made available to the public.

1.12

Problem-solving in science

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define scientific problem
- ✓ outline strategies for scientific problem-solving.

GET THINKING

You are helping to cook muffins and you realise some of them are not cooking properly. What could you do to investigate this problem? What strategies could you use to solve the problem?



Video

Science skills in a minute: Cause and effect

Science skills resource

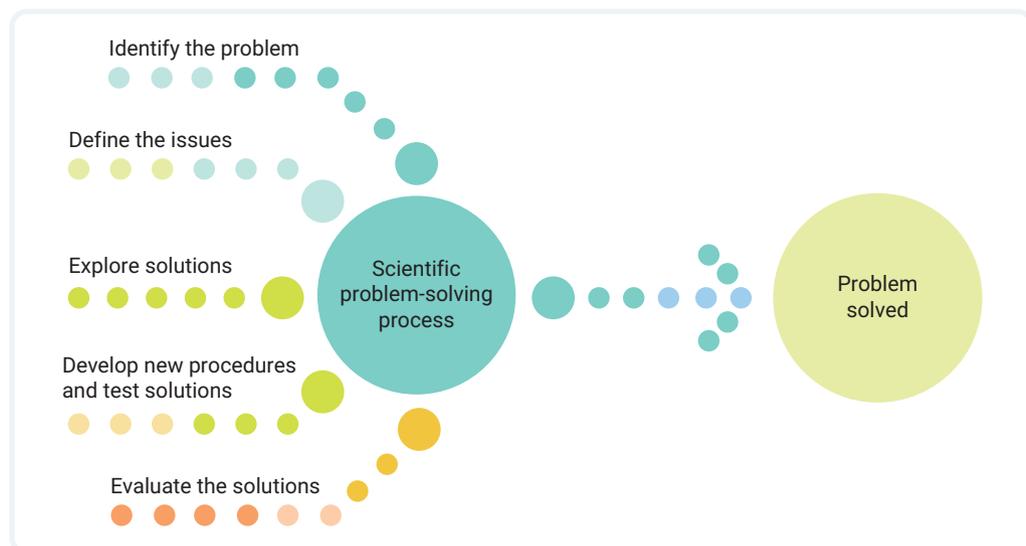
Science skills in practice: Cause and effect in science

What are scientific problems?

Sometimes, during an investigation, problems occur that interfere with the purpose of the research. There isn't a single set of steps to solve a scientific problem. Often, scientists will have to adapt their investigation or repeat steps in the scientific process. Sometimes they need to create new procedures to follow. This is part of the nature of science and the process of working scientifically.

Problem-solving strategies

The main stages of solving problems during research are shown in Figure 1.12.1.



▲ FIGURE 1.12.1 The main stages of solving a research problem scientifically

Let's apply the problem-solving process to an example investigation. You are collecting data about how fertiliser affects plant growth (Figure 1.12.2). As you conduct the investigation, you notice some plants that are receiving the same treatment aren't growing well, despite controlling all the variables.

- Identify the problem – your observations have identified the problem: some plants are getting the same treatment but are growing inconsistently.
- Define the problem – you check all possible causes by collecting further observations. You discover mould on some leaves.
- Explore solutions and develop new procedures – you modify the procedure and repeat the investigation.
- Evaluate the solution – you observe the plants to evaluate if the new procedure has fixed the problem.



▲ FIGURE 1.12.2 A problem during an investigation into the effect of fertiliser on plant growth

Table 1.12.1 lists some strategies used to solve common problems in science investigations.

▼ TABLE 1.12.1 Strategies to solve common problems encountered in science investigations

Common problem	Problem-solving strategy
Anomalies in collected data and measurements	<ul style="list-style-type: none"> • Check apparatus and devices and calibrate if necessary • Check for mistakes in data entry • Check if units need to be converted
Differences in observations between repetitions	<ul style="list-style-type: none"> • Check controlled variables were all kept the same across repetitions
Data collected did not support hypothesis and did not answer the scientific question	<ul style="list-style-type: none"> • Check the procedures used in the investigation • Check how data was collected and recorded • Check the data analysis and type of graph used
Results do not match with previous literature	<ul style="list-style-type: none"> • Do further literature research • Check how data was collected and recorded • Check the data analysis and type of graph • Identify reasons data may differ

Cause and effect: correlation and causation

Examining correlation and cause-and-effect relationships (causation) is helpful in scientific problem-solving. **Correlation** occurs when two variables change together. Some problems are solved by identifying whether there is a cause-and-effect relationship behind the correlation. **Causation** means that one event (the cause) brings about a change in another event (the effect). In a scientific test, causation means the change in the independent variable causes the change in the dependent variable.

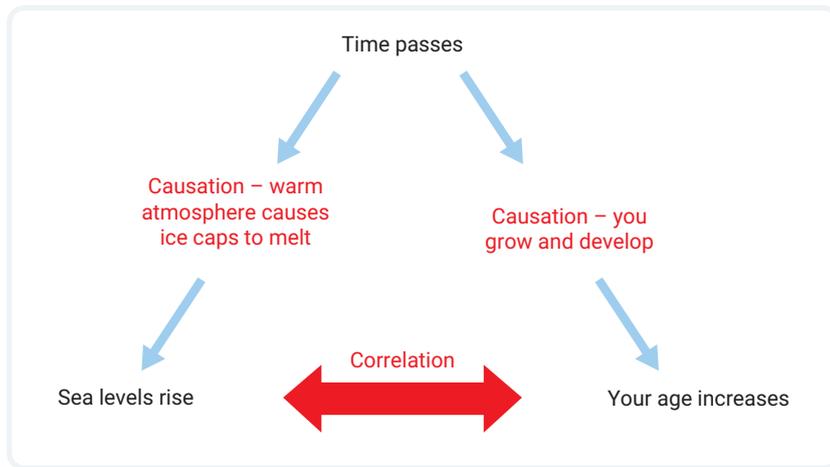
Correlation does not always indicate causation. Sometimes the change in one variable has nothing to do with the change we are observing in another variable.

correlation

a trend in data in which one variable changes consistently as the other variable changes

causation

a relationship in which a change in one variable causes a change in another variable; one event is the result of the occurrence of the other event



For example, think about the correlation between your age and rising sea levels. Over the last 50 years, the sea level around Australia has risen an average of 2.1 mm/year. Your age has increased at a steady rate, too. It's a correlation, but sea level rise is due to a warming planet, not your age changing. So, there is correlation between the variables but not causation (Figure 1.12.3).

▲ FIGURE 1.12.3 There is correlation between rising sea levels and your age, but not causation.

Testing for cause-and-effect relationships

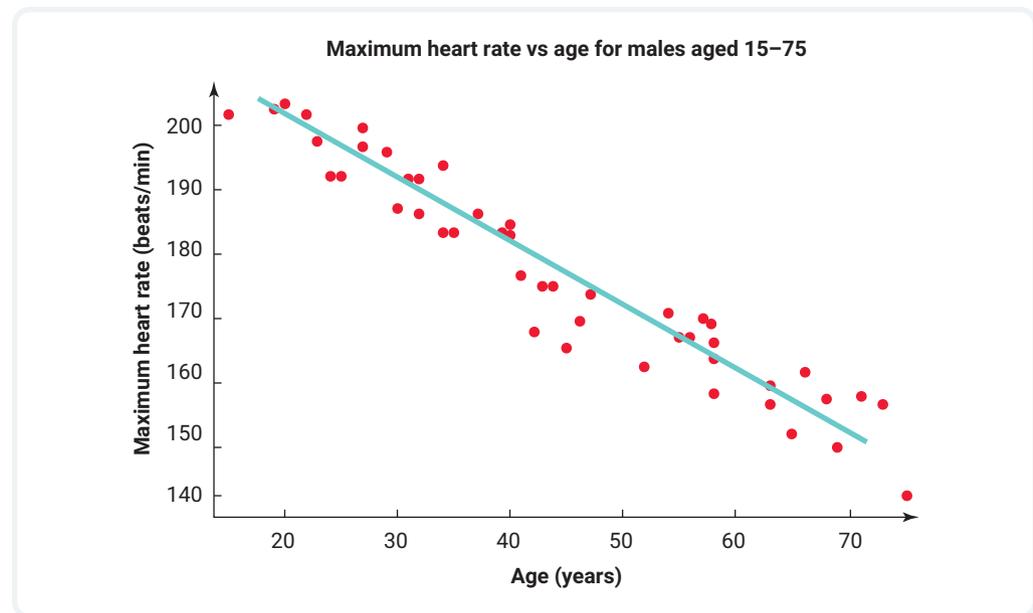
You can see a correlation between the independent and dependent variables more easily when you plot both variables in a graph and draw a line of best fit. For example, you could investigate whether the maximum heart rate of males decreases with age. You would measure the maximum heart rate of males of a range of ages and make a graph. Your results may look like the graph in Figure 1.12.4.

You can use other models, such as mathematical models, to identify causation.

DATA SCIENCE



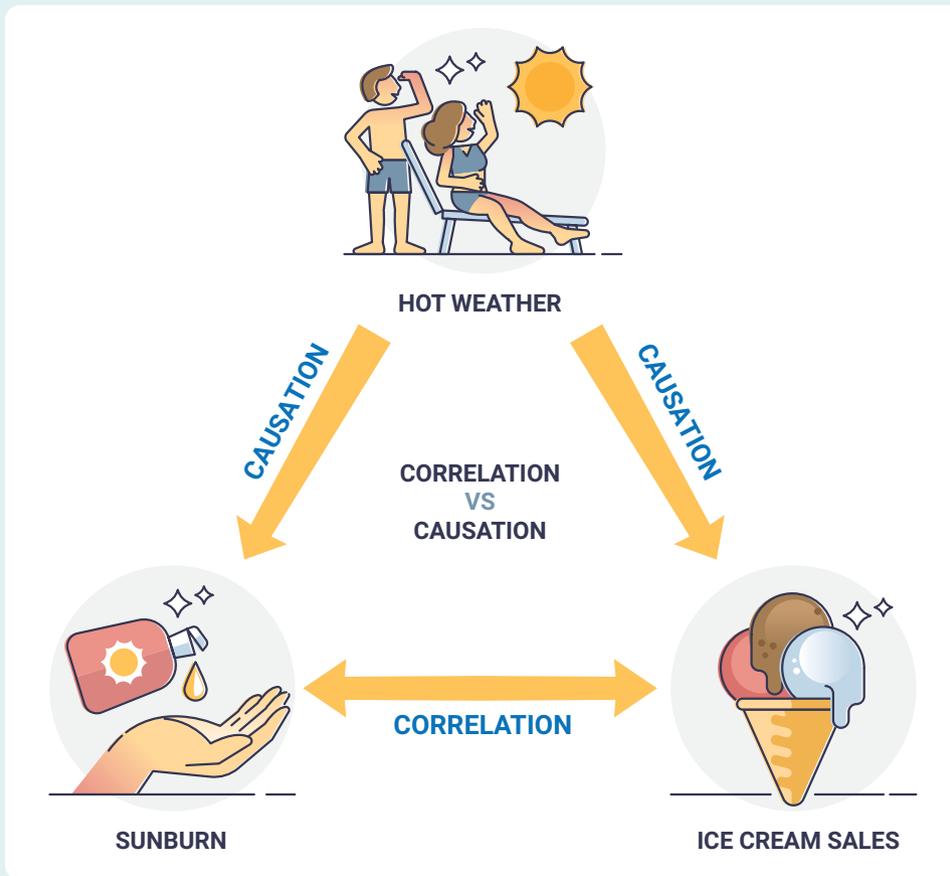
See **Module 2.8** to learn more about using the line of best fit to test for correlation.



▲ FIGURE 1.12.4 Correlation between maximum heart rate and age in males aged 15 to 75 years

1.12 LEARNING CHECK

- 1 **Define** what scientific problem-solving means.
- 2 **Describe** the main steps to solve a problem scientifically.
- 3 Karen is testing how sunlight changes the air temperature inside different coloured bottles. She measures the temperature with a thermometer. She is surprised to find that the temperature doesn't change during the day as she expected. **Create** a flow chart with the steps that Karen should follow to solve this problem.
- 4 The following diagram shows correlation and causation. **Discuss** if there is correlation and causation between hot weather, ice cream sales and sunburn.



- 5 A research team was analysing their results. They realised that there might be an error in the data collection. **List** two strategies that the team could apply to solve the problem caused by the error. **Justify** your strategies.

1.13

Communicating: planning and writing scientific texts

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ identify why scientists communicate their findings
- ✓ list the steps to plan a written scientific text
- ✓ describe the features of common written texts.



Quiz

Science communication

GET THINKING

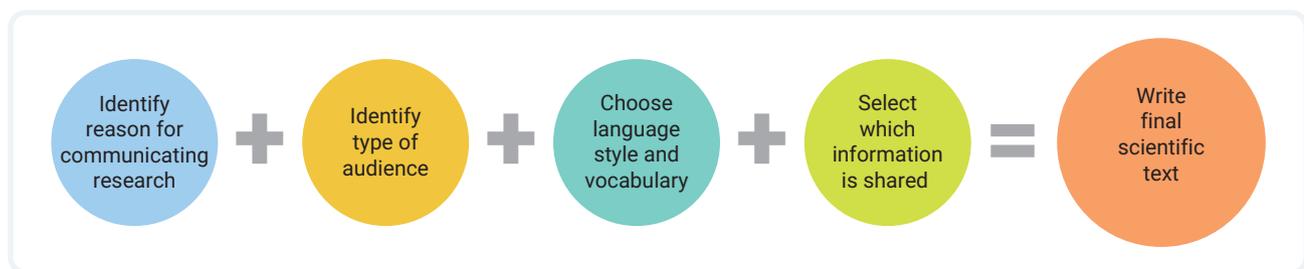
Imagine you are learning about the features of plants. How could you explain this to a kindergarten student? How would you explain the same concept to a Year 11 student?

Types of scientific communication

Scientists communicate their findings to different audiences for different reasons. The audience and the purpose of the communication determine which format or text type is best. This also guides the style of language (formal or informal) and vocabulary (choice of words) the scientist uses.

For example, a scientist presenting their investigation findings to other scientists at a conference will use formats such as lectures and posters, using technical language to share their methods and discoveries in their research field and allow science to advance. They would use a different format and simpler language if they were sharing information with a community group with the aim of informing the public and answering any concerns or questions.

Figure 1.13.1 shows the steps a scientist should follow when planning and writing a scientific text.



▲ FIGURE 1.13.1 The steps in planning a written scientific text

Images in written texts

Scientists use images and figures in scientific texts to help their readers understand their scientific method, results and analysis of their data. Many types of scientific texts use photographs, diagrams, tables, graphs, flow charts and infographics.

When you use images in your scientific reports, make sure you label them correctly. Figures and images need to be simple enough for the intended audience to understand them.

If you use images from secondary sources, you need to check you have permission to use them. You also need to cite all images that you have used from secondary sources.

Types of scientific texts

Table 1.13.1 describes some of the most common types of text used to communicate scientific findings. We will look at science reports in detail in Module 1.14.

▼ TABLE 1.13.1 Types of scientific communications

Scientific text type	Purpose	Audience	Typical features
Magazine article	To share interesting scientific discoveries	Public	<ul style="list-style-type: none"> • Has short length • Uses accessible language, and may introduce and explain scientific vocabulary • Often displays data in the form of photographs or infographics
Scientific podcast	To discuss a scientific topic of interest in depth	Public	<ul style="list-style-type: none"> • Has short duration • Uses concise and general vocabulary • Often focuses on a single topic • Describes and explains data in general terms
Conference presentation	To share new scientific findings	Scientists	<ul style="list-style-type: none"> • May use slides such as from PowerPoint • Uses formal language and technical vocabulary • May include videos • Shows the data collected using graphs and tables • Refers to research done by others
Scientific journal article	To share new scientific findings in detail	Scientists	<ul style="list-style-type: none"> • Follows the format of a scientific report • Uses formal language and technical vocabulary • Is usually written in past tense • May have graphs, tables and maps • Includes long discussion supported by scientific literature • Will have been reviewed by other experts in the same field (called peer review)
Scientific poster	To share summary of new scientific findings in visual format	Scientists	<ul style="list-style-type: none"> • Follows the format of a scientific report • Is usually written in past tense • Has graphs, tables, maps and diagrams • Has a short discussion supported by scientific literature
Scientific website	To explain scientific phenomena	Scientists Students Teachers	<ul style="list-style-type: none"> • Is written in present tense • Includes detailed information about the phenomenon • Includes photographs and diagrams • May include interactive activities or videos • Will have been reviewed by experts in the same field and will be updated regularly

phenomenon
(plural: phenomena)
something that is
observed to exist or occur

1.13 LEARNING CHECK

- 1 **Describe** two reasons scientists communicate their findings.
- 2 **Outline** the steps a scientist would follow to create a scientific text.
- 3 **Describe** the main characteristics of a scientific journal article.
- 4 Arlo visits a university and sees different scientific posters about research that scientists are doing there. **Outline** the features of a poster used for a scientific audience.



- 5 You are invited to communicate the latest findings of your research at a conference. **Discuss** which scientific text types you will use and why.
- 6 **Explain** whether this is a scientific poster. **Justify** your answer.



BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ list the parts of a scientific report
- ✓ write a scientific report.

GET THINKING

This module introduces you to writing a scientific report to share the findings of an investigation. As you work through the module, summarise how to write each section in a flow chart.



Interactive resource
Label: Parts of a scientific report

Science report

Science reports are used to communicate information about scientific investigations. Although the format of the report may vary depending on the purpose and audience, the most common forms are a formal report or a poster. Science reports usually include the sections shown in the following report of an investigation on tomato plants' growth and fertiliser use.

Aim

State the purpose of the investigation.

To investigate the effect of fertiliser on the rate of growth of tomato plants

Hypothesis

State the hypothesis.

If fertiliser is applied to the soil, a tomato plant will grow faster than if no fertiliser is added.

Materials and equipment

List, in detail, the materials and equipment needed, including the amounts of substances.

- 6 tomato seedlings
- 6 small rectangular pots, each measuring 4 cm × 4 cm × 6 cm
- around 300 mL of potting mix
- 25 mL measuring cylinder
- water
- fertiliser (Aquasol)
- electronic balance
- 30 cm ruler (showing millimetres)

Risk assessment

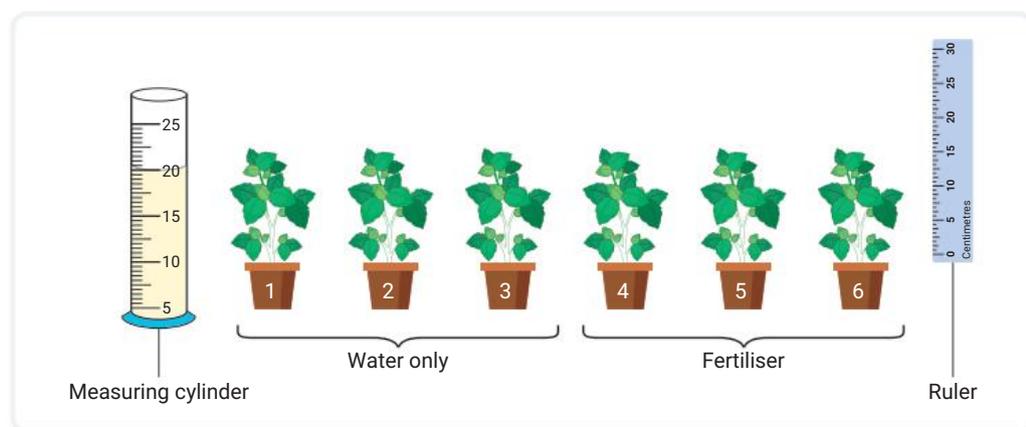
State any hazards and how the risks associated with each hazard can be managed.

Some potting mix contains fungal spores that could be harmful to health. Use potting mix in a well-ventilated area and wear a dust mask and gardening gloves.

Method

Write a detailed method as a series of numbered steps and a labelled diagram or photo.

- 1 The pots were numbered 1–6.
- 2 Each pot was filled with potting mix containing no fertiliser to a height of 3 cm (48 mL of potting mix).
- 3 One tomato seedling was planted in the centre of each pot so that the potting mix was at the same level as the soil the seedling was in.
- 4 The heights of the seedlings were measured with a ruler.
- 5 Pots 1–3 were labelled ‘Water only’.
- 6 10g of fertiliser was sprinkled onto the soil of pots 4–6. These pots were labelled ‘Fertiliser’.
- 7 Each pot was watered with 20 mL of water at the same time each day.
- 8 The heights of the seedlings were measured every second day at the same time, where possible.
- 9 Steps 7 and 8 were repeated for 2 weeks.



▲ FIGURE 1.14.1 The set-up of the experiment

Results

Tables

Include one or more tables of data and any observations.

▼ TABLE 1.14.1 The heights of tomato plants with and without fertiliser over a 14-day period

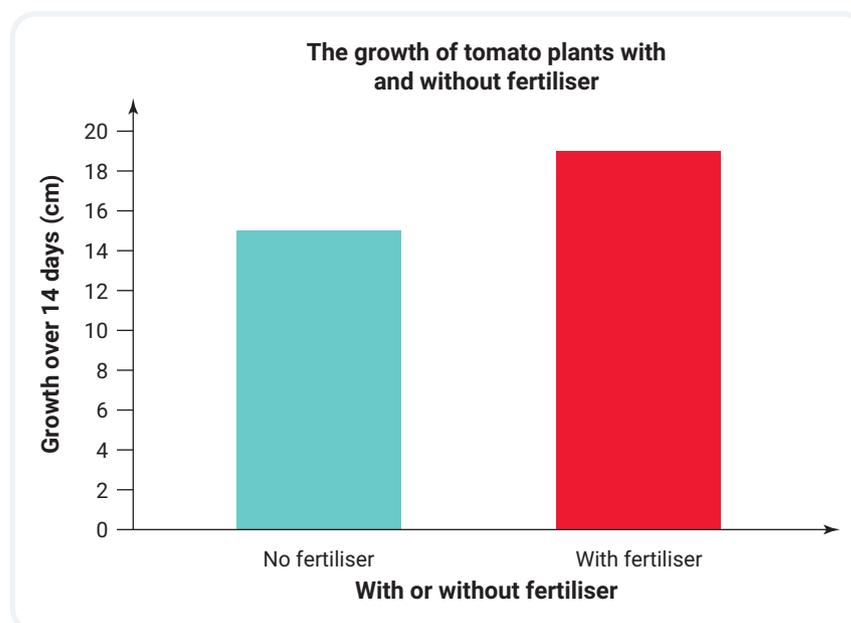
Day	Heights of tomato plants without fertiliser (cm)			Heights of tomato plants with fertiliser (cm)		
	Pot 1	Pot 2	Pot 3	Pot 4	Pot 5	Pot 6
0	17.5	18.5	21	20	19	18
2	19	20	21	21	21.5	20.5
4	22.5	23.5	23	22	24	23
7	25	28	27	26.5	28	26.5
9	27.5	28.5	28	28.5	30.5	28
11	29	29	29	33	33.5	32.5
14	32	33.5	36.5	36	39.5	38.5

▼ TABLE 1.14.2 The increase in heights of tomato plants with and without fertiliser

With or without fertiliser	Increase in heights of tomato plants over 14 days (cm)			
No fertiliser	Pot 1	Pot 2	Pot 3	Average
	14.5	15	15.5	15
With fertiliser	Pot 4	Pot 5	Pot 6	Average
	16	20.5	20.5	19

Graphs

Include a graph of the results.



▲ FIGURE 1.14.2 A column graph showing the increase in height of tomato plants over 14 days with and without fertiliser

Discussion

Discuss the analysis and evaluation of the investigation, including:

- the trend found, the scientific reason for it and whether it supports the hypothesis
- the accuracy, reliability and repeatability of the data, including any anomalies
- the validity of the method
- ways that the investigation could be improved or extended.

Six tomato seedlings were grown under identical conditions, except that 10 g of fertiliser was added to the soil of three plants. Results showed that the tomato plants that received the fertiliser grew, on average, 4 cm more than the ones that did not receive fertiliser. At weekends, the plants did not receive any water. Because this affected all plants equally, the difference in growth would not have been affected.

Both sets of plants initially grew at similar rates until day 9, after which the seedlings with the fertiliser grew more quickly than those without fertiliser.

These results support the hypothesis that a tomato plant in soil with fertiliser grows faster than one in soil without fertiliser. This is because the addition of the fertiliser provided the tomato seedlings with additional nutrients, which helped them to grow faster.

The method fairly tested the hypothesis because all variables were controlled, with the only variation being the addition of fertiliser to half the pots. The method was also appropriate because it measured the height of the tomato plants, which is one valid way of measuring the growth of the plants. This allowed the growth of the plants with and without fertiliser to be compared.

Only the height of the plants was measured. This did not consider the width that the plants grew. Therefore, the accuracy of the growth measurement was limited.

The data for the plants without fertiliser was very reliable, with the growth varying by only 1 cm. The data for the plants with fertiliser was less reliable, with pot 4 growing 4 cm less than the other two pots with fertiliser. Overall, the results are repeatable because the results are similar and each trial conformed to the same trend.

Any future investigations of this type should include more plants under each condition. This would provide more data and minimise problems arising if any of the plants die during the experiment. The investigation could also be extended to test the effect of other fertilisers, the effect of different amounts of fertiliser, the effect of the frequency of adding the fertiliser or the effect of fertiliser on the growth of different varieties of tomato plants.

Conclusion

State the trend and whether it supports the hypothesis.

Results from this experiment support the hypothesis that tomato plants with fertiliser added to their soil grow faster than ones without fertiliser added.

1.14 LEARNING CHECK

- 1 In the tomato plant investigation, what do we call the plants that did not have fertiliser added to their soil? What is the purpose of these tomato plants?
- 2 If you used a different type of potting mix for each tomato plant, what effect might that have on the investigation?
- 3 **Describe** the implications of one of the tomato plants dying during the investigation.
- 4 **Explain** why it is important for the method to be clear, detailed and thorough.
- 5 Can you say conclusively that all tomato plants will grow faster if fertiliser is added? **Explain** your answer.
- 6 Jingyi conducted an experiment measuring the interior temperature of different coloured cars. Her testable question was: is the interior temperature of black cars hotter than other coloured cars? Jingyi's results confirmed her hypothesis. She conducted the experiment once, using the four cars shown below. **Write** five points Jingyi should include in her discussion.

Charlie Hutton/
Shutterstock.com



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Shutterstock.com

Dimitris Leonidas/
Shutterstock.com



Rob Wilson/
Shutterstock.com

1.15 Depth studies

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define depth study
- ✓ outline the types of depth studies
- ✓ describe the steps to conduct a depth study.

GET THINKING

When you walk on the beach, you may see plastic litter, including very tiny pieces of plastic. How could you create a study to investigate the source of those plastics and find ways to reduce their impact?

▶ **FIGURE 1.15.1** Plastic waste, including tiny pieces known as microplastics, is found on beaches all over the world.



David Pereira/Shutterstock.com

What is a depth study?

depth study

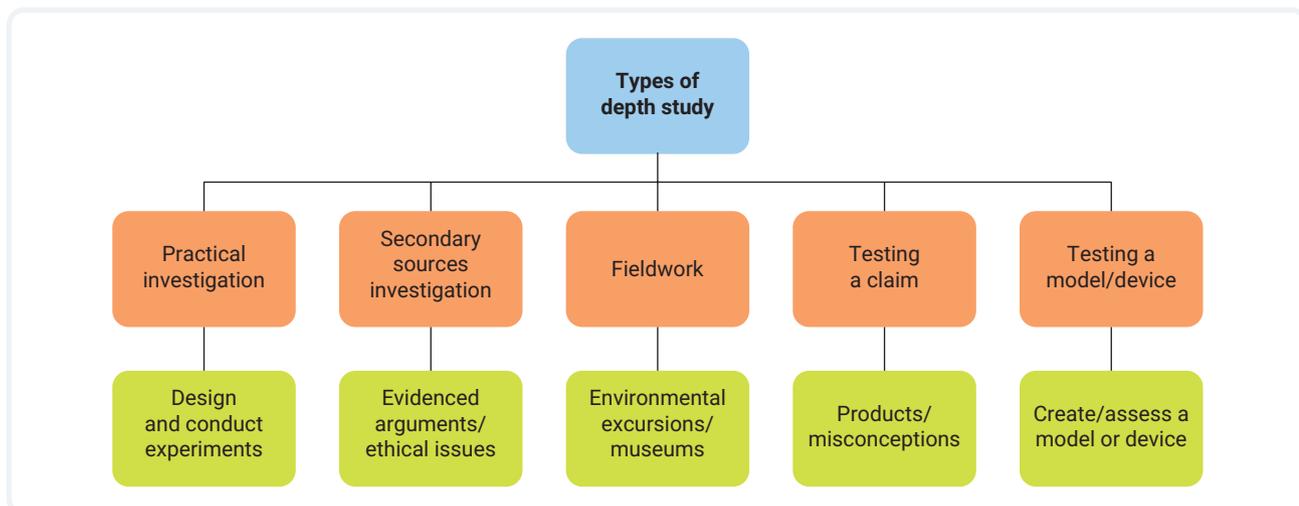
a major research project on a topic of interest and using linked research

A **depth study** is a major research project in which you investigate one or more scientific concepts in detail.

You can use a range of data sources in your depth study. This can be data you collect from an investigation (first-hand data) or data you have analysed from other valid sources (secondary data). You can complete the depth study alone or in collaboration with others. Your teacher will usually give you a set time to complete the study.

Types of depth studies

There are different types of depth studies, depending on the nature and purpose of the investigation. Figure 1.15.2 shows a summary of the types of depth studies.



▲ **FIGURE 1.15.2** There are many types of depth studies.

The tools you use to conduct the depth study will depend on the type of the investigation. Some examples are shown in Table 1.15.1.

▼ TABLE 1.15.1 Common types of depth study, examples and tools you can use

Depth study type	Ideas or examples	Tools
First-hand investigation: • practical investigations • testing a claim and testing a model/device	<ul style="list-style-type: none"> • Conducting experiments • Test an existing device • Create a device or working model and test it • Test a product claim or an idea • Carry out an environmental study 	<ul style="list-style-type: none"> • Scientific report template • Citation tools to create the reference list • Tables and graphs to communicate findings • Quantitative data analysis tools (e.g. averaging, graphing, line of best fit)
Secondary data	<ul style="list-style-type: none"> • Literature review • Evidence-based argument • Theoretical essay • Environmental management plan • Analysis of scientific videos, emerging technologies or ethical issues 	<ul style="list-style-type: none"> • PowerPoint • Canva • Online animation tools • Qualitative and/or quantitative data analysis tools (e.g. averaging, graphing, line of best fit, interviews, survey responses)
Fieldwork	<ul style="list-style-type: none"> • First-hand data collected on an excursion • Data collected from engagement with community experts 	<ul style="list-style-type: none"> • Scientific report template • Essay template • Surveys and interviews

Main steps in a depth study

In a depth study, you follow the working scientifically processes to plan, conduct, analyse and share your findings.

Some of the key activities you will complete as part of the depth study include:

- 1 Develop a testable inquiry question – use this question to drive your research.
- 2 Review secondary sources – look for valid secondary sources that support your ideas and procedure.
- 3 Plan and conduct a fair test – manage and control all of the variables.
- 4 Conduct a risk assessment – identify the hazards you may encounter before, during and after the investigation.
- 5 Collect and process your data – organise your data in tables and graphs.
- 6 Analyse your data – look for patterns and trends, and assess whether your results support or answer your testable inquiry question.
- 7 Communicate – share your findings by selecting a suitable type of scientific text.
- 8 Reference list – include an alphabetical list of the resources and images you consulted or used.

Portfolio of work

portfolio of work

an ordered record of ideas, notes, data and sources about the preparation, carrying out and analysis of a depth study

It is important that you are well organised as you plan and conduct your depth study. Scientists keep a **portfolio of work**, which is often called a log book. In your depth study, you will create your own portfolio of work. This is where you will record:

- your ideas, questions and purpose
- the procedures used to collect data
- your collected data in tables and graphs
- notes of any problems you encounter during your research
- the key ideas for your discussion and conclusion.

You will use the information in the portfolio of work to create a written text to share your findings with your class and teacher.

1.15 LEARNING CHECK

- 1 **Define** depth study.
- 2 **Identify** the importance of the inquiry question in a depth study.
- 3 **Examine** the picture below, taken during a walk in a rainforest. **Describe** what type of depth study you could do related to this environment. Include details about the testable question, sources of data and procedures you would use.



- 4 **Discuss** the importance of having a portfolio of work as you conduct a depth study.

Craig Richard Chanowski/Shutterstock.com

1 REVIEW

REMEMBERING

- 1 **List** the processes involved in working scientifically, beginning with observing.
- 2 What factors must you consider to make an investigation a fair test?
- 3 **State** which variable is shown on the:
 - a vertical axis of a graph.
 - b horizontal axis of a graph.
- 4 What are two different types of graphs? When are they used?

UNDERSTANDING

- 5 **Explain** why it is important to change only one variable in an investigation.
- 6 **Outline** the difference between a method and a procedure. Use this to **explain** why a method is written in past tense.
- 7 Susie is measuring the height of plants. She collects the following data: 0.2 m, 21 cm, 213 mm, 24 cm. **Explain** what is wrong with Susie's data.
- 8 Why is it important that scientific investigations are repeatable?
- 9 **Explain** why it is important for your materials and equipment list to be detailed.

APPLYING

- 10 The hypothesis for an experiment was 'As the mass of a single ice cube increases, the time taken to melt will increase'. **State**:
 - a the independent variable.
 - b the dependent variable.
 - c four controlled variables.

EVALUATING

- 11 Consider the data in the following table, which was collected during an investigation of the temperature during a chemical reaction between vinegar and sodium bicarbonate (baking soda).
 - a **Classify** the data as continuous or discrete.
 - b **Graph** the data.

Time (s)	Temperature (°C)
0	21.0
5	20.5
10	19.0
15	17.5
20	16.8
25	16.5
30	16.1
35	16.0

- c **Describe** the trend shown in the graph.
 - d **Predict** the temperature at 12 seconds.
- 12 An activity in your science class required you to measure the temperature in your science classroom over a 4-hour period. Your results are shown in the table below.

Time (min)	Temperature (°C)
0	14
30	16
60	19
90	21
120	21
180	23
240	17

- a Is this data continuous or discrete? **Justify** your answer.
 - b **Represent** this data as a graph.
 - c What was the highest temperature during the 4-hour period?
 - d **Describe** the trend shown in your graph.
 - e From your graph, determine the temperature of the room at 45 minutes.
- 13 During an experiment, the mass of limestone that dissolved was measured. The results were 5, 7.2, 6.3, 5.5, 5.8, 6, 4.9 and 6.7 g. **Calculate** the mean of this set of data.

14 Olivia and Ethan decided to test whether red flowers lasted longer as cut flowers than white flowers. They put a red rose in a small cup of water on the bathroom shelf, and a white carnation in a large jar of water on the bench in the garden shed. After 3 days, the white flower had died, but the red flower was still alive. They concluded that red flowers lasted longer than white flowers.

- a Explain** why this was not a fair test.
- b** Was Olivia and Ethan's conclusion valid?
- c Rewrite** their method to make this a fair test.

15 In your opinion, what might happen if every scientist reported their scientific discoveries in a different way?

16 Consider the information represented in the graph below.

- a** What type of graph is shown?
- b State** the independent variable.
- c State** the dependent variable.
- d List** three variables that would have been controlled in this investigation.
- e Describe** the trend shown in the graph.

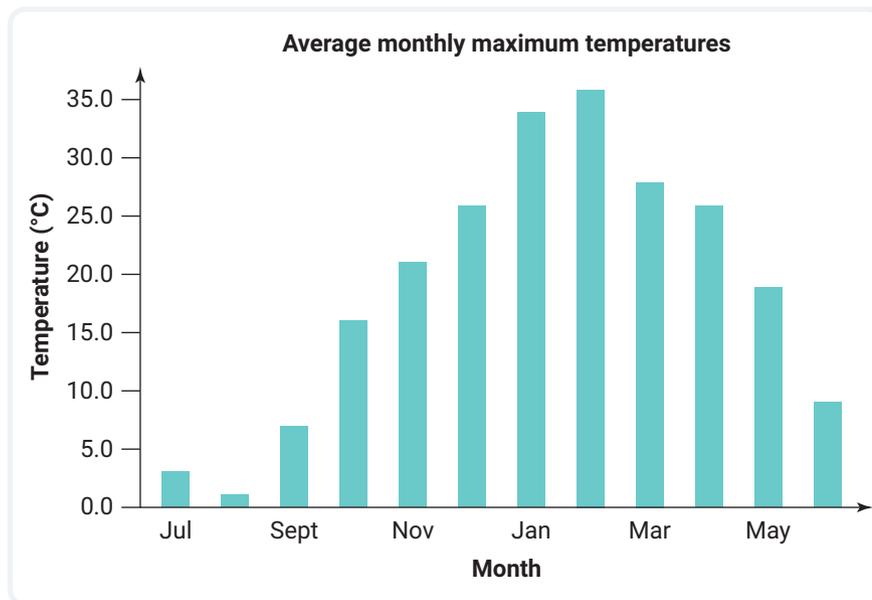
17 A scientist claimed to have made an important discovery but did not follow scientific processes or write a scientific report. What are the implications of this? Would that scientist's findings be taken seriously?

CREATING

18 Write a hypothesis for each question.

- a** Why do my black clothes get hotter in summer than my white clothes?
- b** What would make my model car go faster?
- c** Will plants grow more if I give them more water?
- d** How does the type of mug affect how quickly a cup of coffee goes cold?
- e** Does ice melt faster if left out on a tray or put in room temperature water?
- f** Do diet drinks help you lose weight?

19 Plan and conduct an investigation to test the question 'Do people prefer to read novels as a hard copy or on a device?' **Create** a scientific report to share your findings.



DATA SCIENCE 1

SYLLABUS OUTCOMES

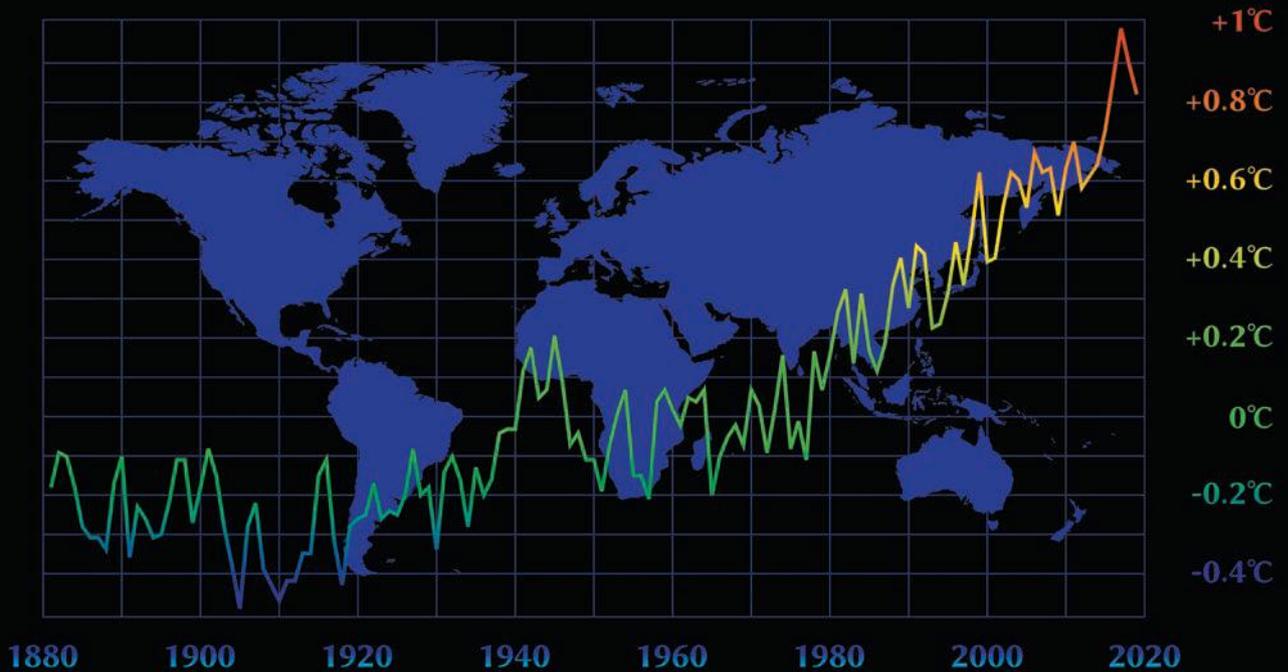
A STUDENT:

- ▶ explains how data is used by scientists to model and predict scientific phenomena
SC4-DA1-01
- ▶ uses data to identify trends, patterns and relationships, and draw conclusions
SC4-WS-06
- ▶ identifies problem-solving strategies and proposes solutions SC4-WS-07

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THE CHAPTER RELATED TO THIS FOCUS AREA IS:

- ▶ **CHAPTER 2 – DATA SCIENCE**



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2

Data science

2.1 What is data? (p. 60)

Data is information collected in a consistent and systematic way that is used for a range of scientific purposes.

2.2 Quantitative data (p. 64)

Quantitative data is information you can count or measure. It is expressed as sets of numbers.

2.3 Qualitative data (p. 68)

Qualitative data is information you cannot count or measure. It can be expressed as text or images.

2.4 Using data in science (p. 72)

Scientific data is testable and comes in many different forms.

2.5 Secondary data (p. 75)

Secondary data is data collected by someone else. Using secondary data has advantages and disadvantages.

2.6 Collecting data (p. 78)

Scientists collect data in a variety of ways and plan how to gather accurate and reliable data.

2.7 Analysing datasets: preparation and summaries (p. 81)

Datasets must be organised and summarised before they can be analysed.

2.8 Analysing datasets: trends and correlations (p. 84)

Datasets are analysed to identify trends and correlations, and to draw conclusions.

2.9 Scientific models (p. 90)

Scientists use models to explain and predict real-world phenomena.

2.10 Analysing models (p. 94)

Scientists analyse models to explain and predict phenomena, and to improve the accuracy of models.

2.11 SCIENCE IN CONTEXT: Data in meteorology (p. 97)

Scientists collect weather data in many ways to use in weather and climate models and to predict weather and climate changes.



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The ocean is warming and sea levels are rising. We know this because of scientific data and the use of models to understand the past and predict possible futures. During the last decade alone, global sea levels have risen an average of 3.6 mm per year. Rising sea levels affect coastal communities through storm surges, flooding and higher rates of coastal erosion.

- ▶ Water expands when it is heated. How does the warming ocean affect sea levels?
- ▶ As ice on land and ice shelves melt, the water is added to the ocean. Which type of ice contributes more to sea level rises?
- ▶ As the weight of ice is removed from Antarctica, Antarctica will rise, lifting part of the ocean floor. How will this affect sea levels?
- ▶ What is the evidence for rising sea levels and how is it gathered?

▲ FIGURE 2.01 As oceans warm, less sea ice forms each winter in polar regions.

#2 DIVE INTO SCIENCE!

At the end of this chapter, you can complete Science in Depth Study #2. You can use the information you learn in this chapter to complete the depth study.

Assessments

- Prior knowledge quiz
- Chapter review questions
- End-of-chapter test
- Depth study: Research project

Videos

- Science skills in a minute: Secondary sources (2.5); Collecting and organising data (2.7)
- Maths in science videos: Histograms (2.2); IQ scores (2.3); Origin of pie charts (2.4); Mean, median and mode (2.7); Correlation and causation (2.8); Distorted graphs (2.8); Analysing different graphs (2.10)

Science skills resources

- Science skills in practice: Evaluating secondary sources (2.5); Collecting and organising data (2.7)
- Extra activities: Playing with Python (2.7); Working with spreadsheets (2.8); Analysing clusters (2.8); Chemical models (2.9)

Interactive resources

- Label: Penguin data (2.3)
- Drag and drop: Statistics (2.7)
- Simulation: Pendulum lab (2.10)
- Crossword: Data science (2.10)

2.1 What is data?

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define data
- ✓ identify sources of data used in science and other areas of inquiry
- ✓ describe how digital footprints are generated
- ✓ explain the importance of controlling digital footprints.



Video activity
Digital footprints

GET THINKING

Think about three photographs of you from when you were 3, 7 and 10 years old. What sort of information could you gather from the photographs? Is the information from the photographs data?

data

the numbers or observations collected during an experiment; information gathered for a scientific inquiry

information

facts about an object, event or process

Data

Data is information that has been collected in a systematic way. We use data to describe, test and predict:

- objects
- ideas
- processes.

Data can include names, quantities, descriptions, locations, pictures, maps, sets of numbers, and statistics such as averages. We gather data as information for different purposes (Figure 2.1.1). When we conduct an experiment, the measurements and observations we make are not random. Generally, we collect data to advance our knowledge and understanding of the world.

Scientists collect and analyse data as part of working scientifically. They do this to:

- describe something in detail
- identify and describe a trend or pattern
- test an idea, a hypothesis or a model
- predict an event or outcome.

In Chapter 1, we defined data as the numbers and observations collected during an experiment. But many people who are not scientists still use data in a scientific way. People in the business world use scientific methods to analyse information and so do people who design products. As you study this chapter, think of data as information used in a scientific way.



▲ FIGURE 2.1.1 Information gathered by scientists in an experiment is data.

Data and science

To better understand the importance of data in science, think about how we collect and use data to test a hypothesis. For example, think about the hypothesis:

On average, students who play football run 50-metre sprints faster than students who do not play football.

These are the steps you would need to follow to use data to scientifically test this hypothesis:

- 1 Decide on the procedure to collect the data.
- 2 Collect accurate numerical data on the time it takes each class member to run 50 metres and match it to the descriptive data about each class member’s football participation.
- 3 Organise the data into times for players and non-players and summarise the data by calculating the averages for each category.
- 4 Analyse the data to make a judgement on whether the data supports the hypothesis.
- 5 Present the data and its analysis to show you have conducted a fair test and have evaluated your procedure and data.

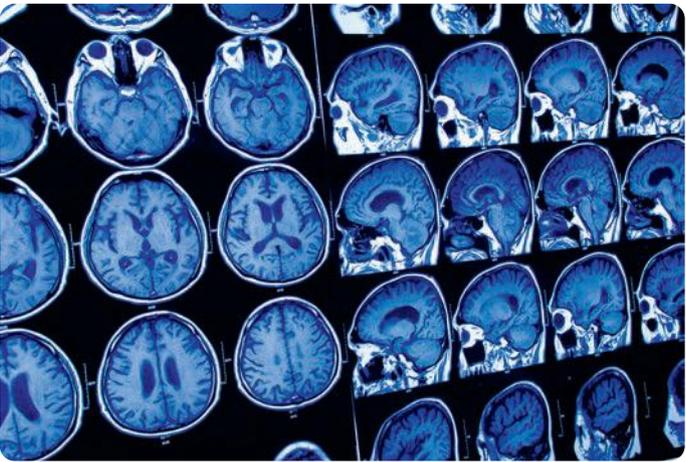


Monkey Business Images/Shutterstock.com

▲ FIGURE 2.1.2 Do football players run faster on average than non-football players?

Uses of data in society

Scientists generate huge amounts of data in large and small experiments. For example, the US space agency NASA gathers data to understand our solar system and the universe. Radiographers generate data when they create MRI and X-ray images (Figure 2.1.3). Drug company scientists generate data in the development and testing of drugs, and data is used to test engineering ideas in the development of rockets and aircraft. Scientists who study weather and climate also require enormous amounts of data to do things such as run models to understand and predict climate change.



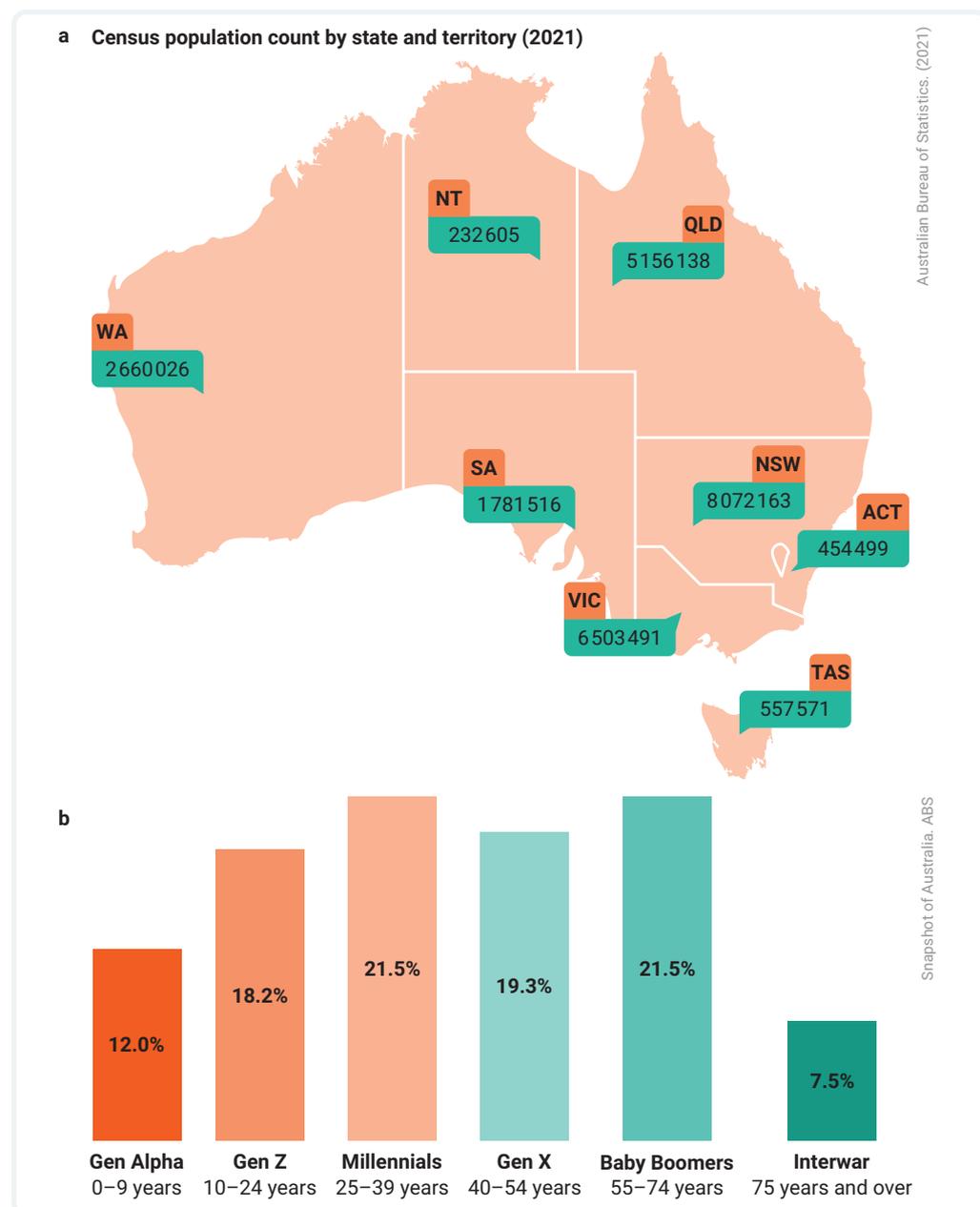
Tushchakorn/Shutterstock.com

▲ FIGURE 2.1.3 Medical imaging, such as magnetic resonance imaging (MRI), generates large amounts of data.

digital system
machines with digital electronics and software that generate or store data

Many places besides science laboratories and hospitals generate data. **Digital systems**, machines with digital electronics and software, generate data. Computers, ticket readers on buses, smartphones, self-service checkouts at the supermarket and electronic smart speakers are examples of digital systems. Designers use data to create 3D models of products, games designers generate data in creating new games and social researchers gather data using questionnaires, surveys and interviews.

The Australian Government collects extensive information about many areas of society. An example is the national census, a nationwide survey that occurs every five years (Figure 2.1.4). The government uses this census data scientifically to identify trends and patterns in Australian society. This analysis is used to plan and make predictions about our future. For example, governments use data about population growth and location to decide where hospitals and schools are needed.



► **FIGURE 2.1.4** The Australian census survey produces lots of data. This data is processed and presented in different ways, such as (a) this map showing the population in each Australian state and territory, and (b) this graph showing the percentage breakdown of Australia's population by generation.

2.2 Quantitative data

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe how quantitative data is collected
- ✓ outline how quantitative data can be presented
- ✓ explain the difference between discrete and continuous data.



Maths in science
video
Histograms

Quiz
Quantitative data

GET THINKING

Scientists use instruments to measure the properties of objects and how things change over time. Make a table of five physical properties of one of these materials: copper, steel, wood, plastic or cotton. In the table, include the units of measurement for each of those properties.

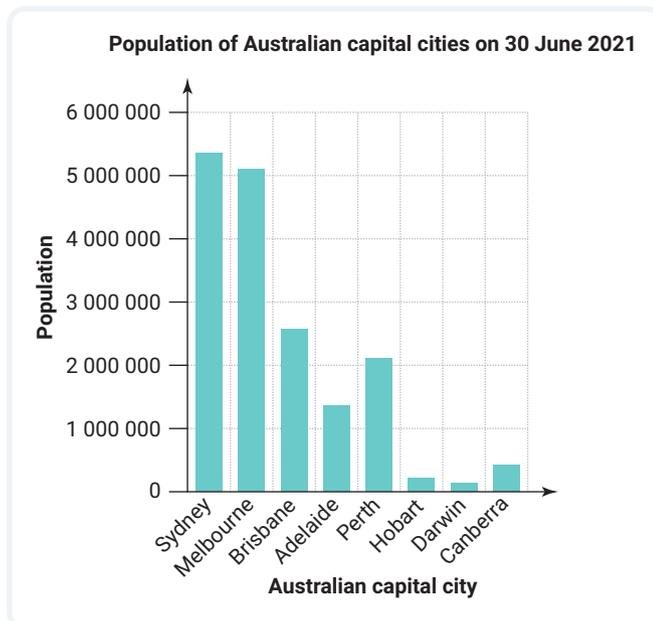
We described **quantitative data** in Chapter 1 as information in the form of sets of numbers. Quantitative data includes sets of measurements and numbers used to summarise those sets. Quantitative data can be discrete or continuous. Scientists use different methods to collect and analyse discrete and continuous data.

Discrete data

Discrete data is data you can count. If you count the number of flowers within a set area, or the number of birds in a gum tree, or the number of stars you can see, you are collecting discrete data.

Organising discrete data

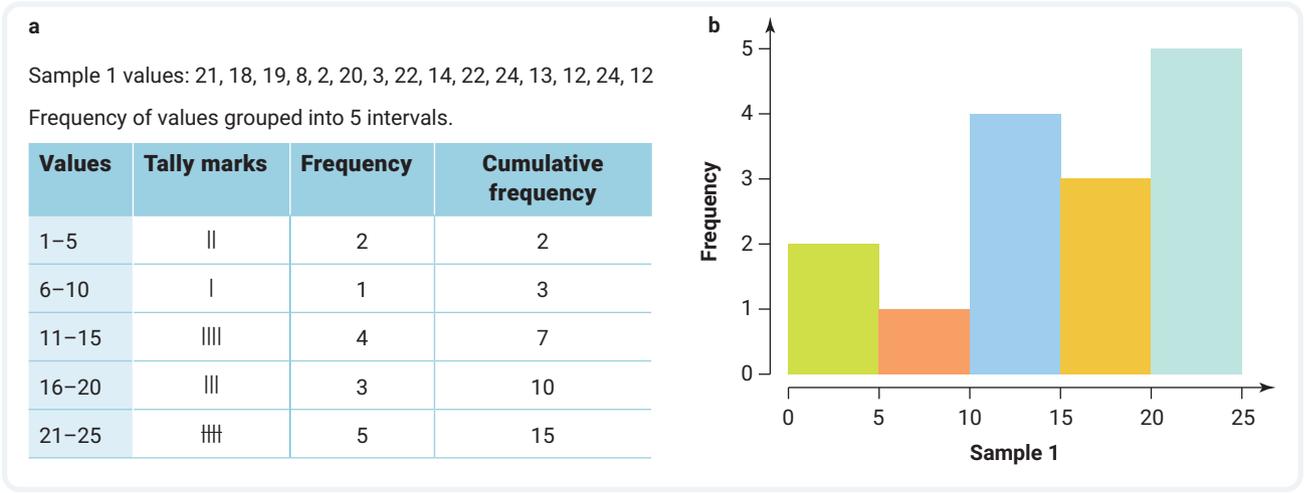
As we saw in Module 1.10, discrete data is often presented in column graphs. Figure 2.2.1 shows an example of discrete data presented in a column graph.



▲ FIGURE 2.2.1 Discrete data presented in a column graph

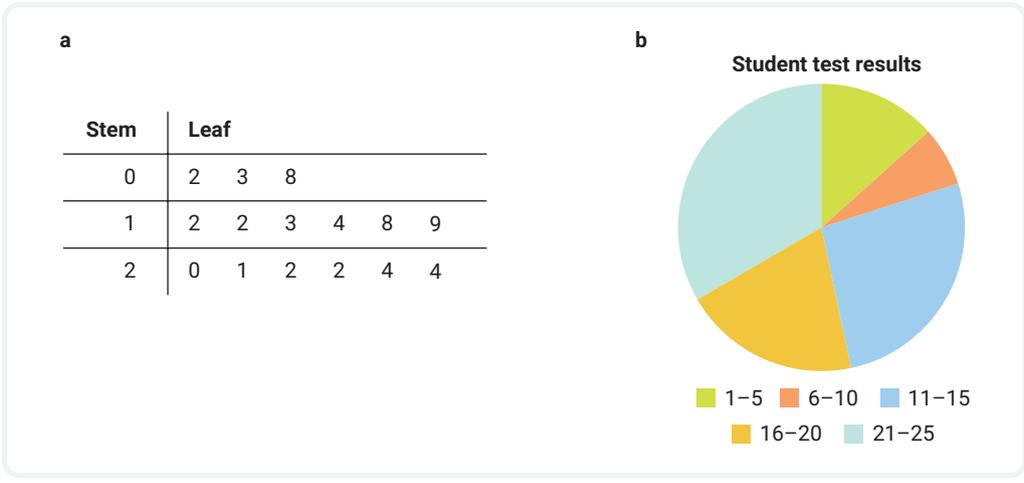
We also often use tallies and frequency distribution tables when we collect discrete data. Figure 2.2.2a shows a tally of 15 values organised into five class intervals. Imagine these are the marks that 15 students achieved in a science test.

The frequency column shows how often values in a class interval occur. To work out the number of class intervals to use, you first work out the total range of the values (by considering the largest and smallest values). In the example shown in Figure 2.2.2, values range from 2 to 25. Because 5 divides 25 evenly, it is a good choice for dividing the values into groups. So, the first group is 1 to 5, the second 6 to 10, and so on. The last column in the table is a cumulative frequency column. You can present frequency distributions as a histogram, as shown in Figure 2.2.2b. Unlike the column graph in Figure 2.2.1, there is no space between each group in a histogram.



▲ FIGURE 2.2.2 (a) A frequency table and (b) a histogram for 15 selected values

Other graphs you can use for displaying discrete data like the students’ test scores are scatter plots and stem-and-leaf plots (Figure 2.2.3a), which separate the digits of a data value into a stem (first few digits) and a leaf (usually the last digit). Pie charts can also be used to display discrete data (Figure 2.2.3b). It is usually easier to interpret discrete data using a column graph or a histogram rather than a pie chart.



▲ FIGURE 2.2.3 You can also present discrete data in (a) stem-and-leaf plots and (b) pie charts.

Continuous data

Continuous data is data you can measure. Examples of continuous data include height, length, mass and temperature. Continuous data is called ‘continuous’ because it can take an **infinite** number of values between any two values. For example, imagine you measured the length of a piece of wire as 33 millimetres (mm). It is likely that the wire’s true length is not *exactly* 33 mm and could in fact be something like 33.43125 mm! So, while the values of 33 and 34 millimetres appear close to each other on a ruler, there is an infinite number of values between them.

infinite
endless, without limits

Measuring continuous data

In science, there is always the possibility of a small error in measurement. We assume it is equal to half the smallest unit on our measuring device. So, if a ruler measures in millimetres, we assume the true measurement may be up to half a millimetre either side of the measurement.

In the science laboratory, we use different instruments to measure the different properties of objects and substances, such as length, mass, volume, temperature and time. We measure each of these properties using different units. All these measurements are continuous data.

Organising continuous data

The graph used most often for continuous data is the line graph. We can also use histograms to represent continuous data if we first organise the data into **consecutive** class intervals.

consecutive

following one another in order

Continuous or discrete data?

The easiest way to check if data is continuous or discrete is to determine if you can measure it (continuous data) or count it (discrete data). You can test this by halving the unit of measurement and seeing if it still makes sense. For example, if you measured something that took 6 seconds in an experiment, then half of a second makes sense. (Figure 2.2.4a). Therefore, measuring time gives you continuous data. But if your experiment involved counting live fish in an aquarium, then half of a fish really does not make sense (Figure 2.2.4b). The number of fish is therefore discrete data.



▲ FIGURE 2.2.4 (a) Time measured in seconds is continuous data; (b) the number of fish in an aquarium is discrete data.

Datasets and tables

A **dataset** is a collection of related data. When we perform an experiment to collect data, or summarise data from secondary sources, we organise the data and create a dataset. Every column in your table should represent a particular variable and each row represents a single record. For example, Table 2.2.1 shows the data measured for 10 out-and-back swings of a pendulum measured three times for each different length of a pendulum. The time for 10 swings is the dependent variable (the variable you're measuring), and the length of the pendulum is the independent variable (the variable you're changing).

dataset

a collection of related data

▼ TABLE 2.2.1 How the time for 10 swings of a pendulum changes with the length of the pendulum

Length (m)	Time for 10 swings out and back (seconds)			
	Trial 1	Trial 2	Trial 3	Average
0.30	11.04	11.00	10.98	11.01
0.51	14.30	14.33	14.30	14.31
0.70	16.89	16.76	16.74	16.80
0.89	18.92	18.90	18.93	18.92
1.10	21.07	21.05	21.02	21.05

In data science, a well set-out table of results is important. Poorly structured tables may lead to errors in your analysis and conclusions.

Statistics and continuous data

We refer to the numbers that summarise datasets as statistics. A **statistic** is a value derived from a dataset, such as a mean or a maximum value. **Statistics** is also the name of a mathematical branch of science that deals with the collection, analysis and interpretation of numerical data.

statistic

a value derived from a dataset, such as a mean or a maximum value

statistics

the mathematical branch of science dealing with the collection, analysis and interpretation of numerical data

2.2 LEARNING CHECK

- 1 **Define** quantitative data.
- 2 What sort of data do you collect using instruments such as rulers and thermometers?
- 3 **Identify** whether the data in the table below is continuous or discrete. **Justify** your reasoning.

Nitrogen concentration (mg/L)	Number of organisms in the microscope field of view			
	Count 1	Count 2	Count 3	Average
0	15	13	14	14
35	11	10	21	14
70	45	21	61	42
140	74	85	63	74

- 4 **Identify** two types of graphs you can use to represent continuous data.
- 5 **Construct** a graph using the data in the table above to show how the average number of organisms changes with increasing nitrogen concentration.

2.3 Qualitative data

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe how qualitative data is collected and used
- ✓ identify sources of qualitative data used in science.



Maths in science
video
IQ scores

Interactive resource
Label: Penguin data

GET THINKING

Figure 2.3.1 is a photo of a type of penguin. Can you describe this animal? Are there things we study that are easier to describe with images or words rather than numbers? Make a list and share it with a partner.



▲ FIGURE 2.3.1 How could you describe this penguin?

Qualitative data is important in developing many scientific ideas. Biological classification, for example, is based on the qualitative description of organisms and the grouping of organisms with similar features. How could you summarise the features of the penguin in Figure 2.3.2a, compared with the three other species of penguins shown (Figures 2.3.2b, c and d)? You can use measurements as part of the description, but overall, the description is qualitative data.

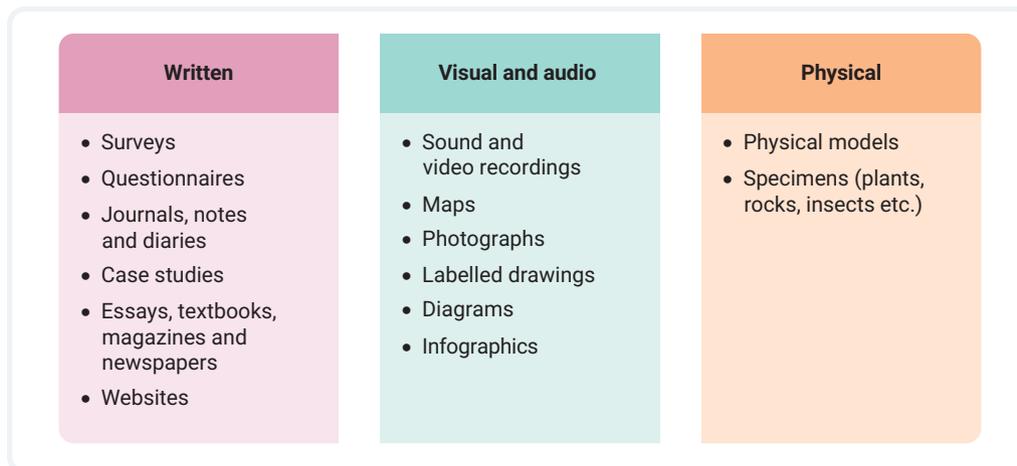


▲ FIGURE 2.3.2 You can describe and compare four species of penguins using qualitative data: (a) rockhopper penguin; (b) Gentoo penguin; (c) king penguin; (d) little penguin.

Sources of qualitative data

Qualitative data is descriptive, **non-numerical** information that relates to a quality, type, choice or opinion. There are many sources of qualitative data (Figure 2.3.3). In investigations, we can collect qualitative data ourselves or we can use data collected by others.

non-numerical
information or a quality
that isn't a number



▲ FIGURE 2.3.3 Examples of sources of qualitative data

Qualitative data in investigations

Qualitative data is important in laboratory investigations. It provides us with information that numbers alone cannot. It is important you write notes on what you observe in an experiment, even if most of the investigation is about gathering quantitative data. You may observe something that helps explain a trend or unusual measurement in your quantitative data. For example, noting that there was a breeze when someone entered the room may help explain changes in the heat produced by a Bunsen burner flame.

We rely on our senses, particularly sight, hearing, touch and smell, when making qualitative observations in a laboratory. For safety reasons, we don't use our sense of taste. For example, in a chemical experiment you might feel a test tube becoming warm, see a colour change, see and hear bubbles form, and smell a gas being produced. Put together, all these qualitative observations make a qualitative dataset.

Qualitative data about a place or a situation may vary between observers. The way we describe the world depends on how our senses work and our own experience. Like many aspects of science, the quality of our observations often improves with practise and experience.



▲ **FIGURE 2.3.4** Photographs are one of the many types of qualitative data collected during fieldwork.

data scientists

people who use scientific skills to analyse and interpret complex digital data

Collecting qualitative data

You can collect and record qualitative data in many ways. You can make observations in the form of text, images, videos or audio recordings (Figure 2.3.4). Interviews generate qualitative data, as do surveys and questionnaires. Online communities, social media platforms and online stores generate a lot of qualitative data.

Data scientists analyse large amounts of data to find trends and patterns. For example, data scientists use the vast amounts of data on the internet to study behaviour. If you use a music streaming platform, it will record and store what you play

and search for. By comparing your data against data from millions of other users, the platform can predict what other songs or musicians you might like.

Processing and analysing qualitative data

Analysing qualitative data involves interpretations and judgements. To summarise large amounts of qualitative data, we can group the information into categories. Table 2.3.1 describes three forms of qualitative data you might use in your investigations.

▼ **TABLE 2.3.1** Types of qualitative data

Data type	Definition	Example
Binary	A variable that is either present (1) or absent (0)	In geology, a volcanic rock may have evidence of gas bubbles, or it may not.
Nominal	A variable that is from a set of categories	In biology, there are different types of primates: lemurs, baboons, humans, apes, monkeys.
Ordinal	A variable that can be ordered	A common form of ordinal data is the five-point scale used in questionnaires: 'strongly agree', 'somewhat agree', 'neither agree nor disagree', 'somewhat disagree' or 'strongly disagree'.

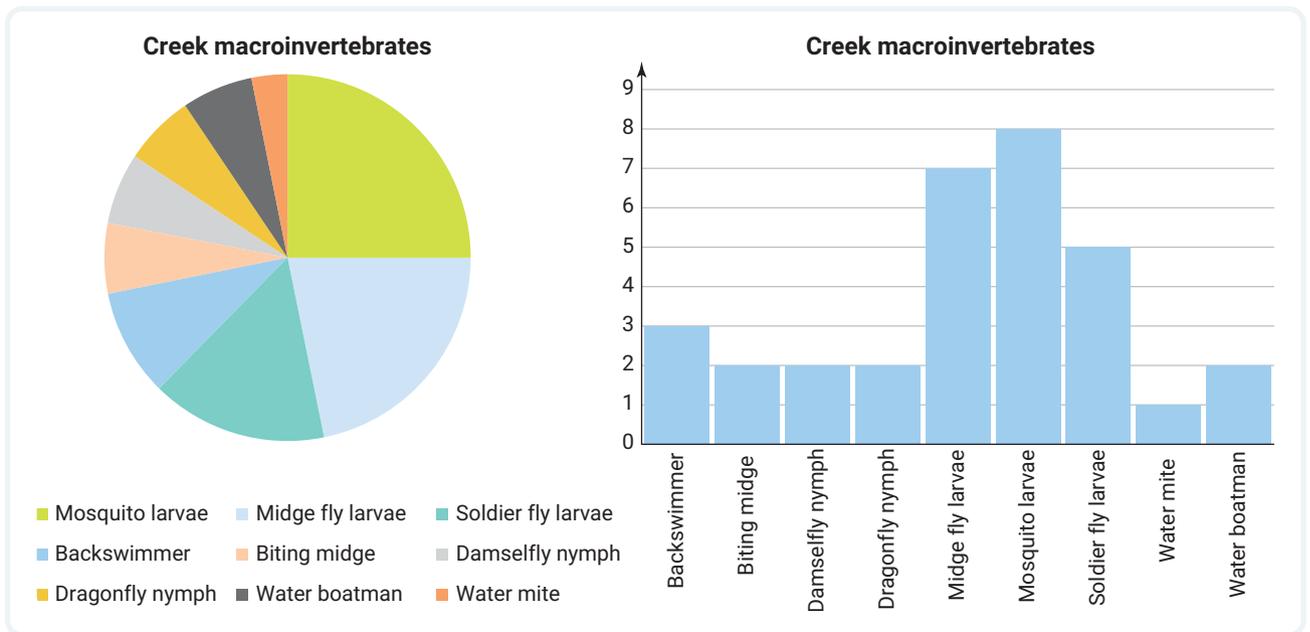
Qualitative data is usually summarised and presented in a table, column graph, pie chart or written summary.

Multiple sources of qualitative data are often used when research is presented as a **case study**, which is a detailed analysis and description of a particular issue or person.

Graphs and pie charts summarise the groups or categories identified in an investigation. Some chart types are easier to interpret than others. In Figure 2.3.5, the dataset represented in the pie chart and the column graph is the same. It is easier to see numbers for each category in the column graph, so use column graphs in preference to pie charts.

case study

an in-depth analysis of an issue or situation



▲ FIGURE 2.3.5 A pie chart and a column graph showing the same dataset, a summary of the macroinvertebrates identified in a stream

2.3 LEARNING CHECK

- 1 **State** the definition of qualitative data.
- 2 **Describe** three sources of qualitative data you might gather during a science investigation.
- 3 **Explain** why a map is a form of qualitative information.
- 4 **Reorganise** the table below so it correctly describes the features of qualitative and quantitative data.

Qualitative data	Quantitative data
Based on numbers	Descriptive
Based on information from the senses	Countable or measurable
Use of surveys, written text and images	Use of instruments and units of measurement
Analysed using statistics to describe features and trends	Analysed by grouping data into themes or categories

- 5 In a science investigation, you collect the following data:
 - i The blue liquid has a sweet smell.
 - ii The green liquid is hotter than the blue liquid.
 - iii The blue liquid has 3 mL more volume than the green liquid.
 - iv The rock sinks to the bottom of the beaker in both liquids.
 - v Bubbles form in the green liquid.
 - vi The temperature of the green liquid is 42°C.
 - a Which of the data is qualitative? **Justify** your answer.
 - b Could you change any of the qualitative data collected into quantitative data? How would you collect the data?

2.4 Using data in science

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ compare data collected from scientific inquiries with data from non-scientific approaches
- ✓ describe a range of data sources and their applications.



Maths in science
video

Origin of pie charts

Quiz

Data use in science

GET THINKING

Rock pools are a rich source of information. What makes the observations and measurements from a rock pool scientific? How is scientific data different from a simple photograph or information in a poem?



Vara I/Shutterstock.com

▲ FIGURE 2.4.1 An ocean rock pool

The nature of scientific data

reliable

consistent; able to be trusted

replicated

repeated to obtain similar results

validity

the extent to which an investigation tests a hypothesis

peer review

evaluation of scientific work by other experts to assess validity and quality

Scientists use many forms of data to test ideas and create new knowledge about the world. New scientific knowledge is used for a variety of purposes because it is **reliable**.

We can use data scientifically to:

- improve our understanding of things
- solve everyday problems
- develop new technology
- provide useful information for governments to address social, health, environmental and economic issues.

Data produced by scientific processes is reliable because these processes can be **replicated**. We can repeat an experiment if it has a good method and careful measurement. If an experiment is repeated many times and similar results are

produced, scientists gain confidence in the data. In turn, the scientific community accepts scientific ideas generated from reliable data because these ideas are supported by evidence and tested predictions.

To ensure the **validity** and quality of new scientific knowledge, scientific reports are put through **peer review**. Peer review means that a panel of experts in the subject evaluate the written report of the scientific work before it is published. If a science paper passes peer review, it may be published in a scientific journal (Figure 2.4.2). Peer review helps to ensure scientific knowledge is based on scientific processes and good data.



qushie/Shutterstock.com

▲ FIGURE 2.4.2 Journals record scientific data and advances.

Science versus pseudoscience

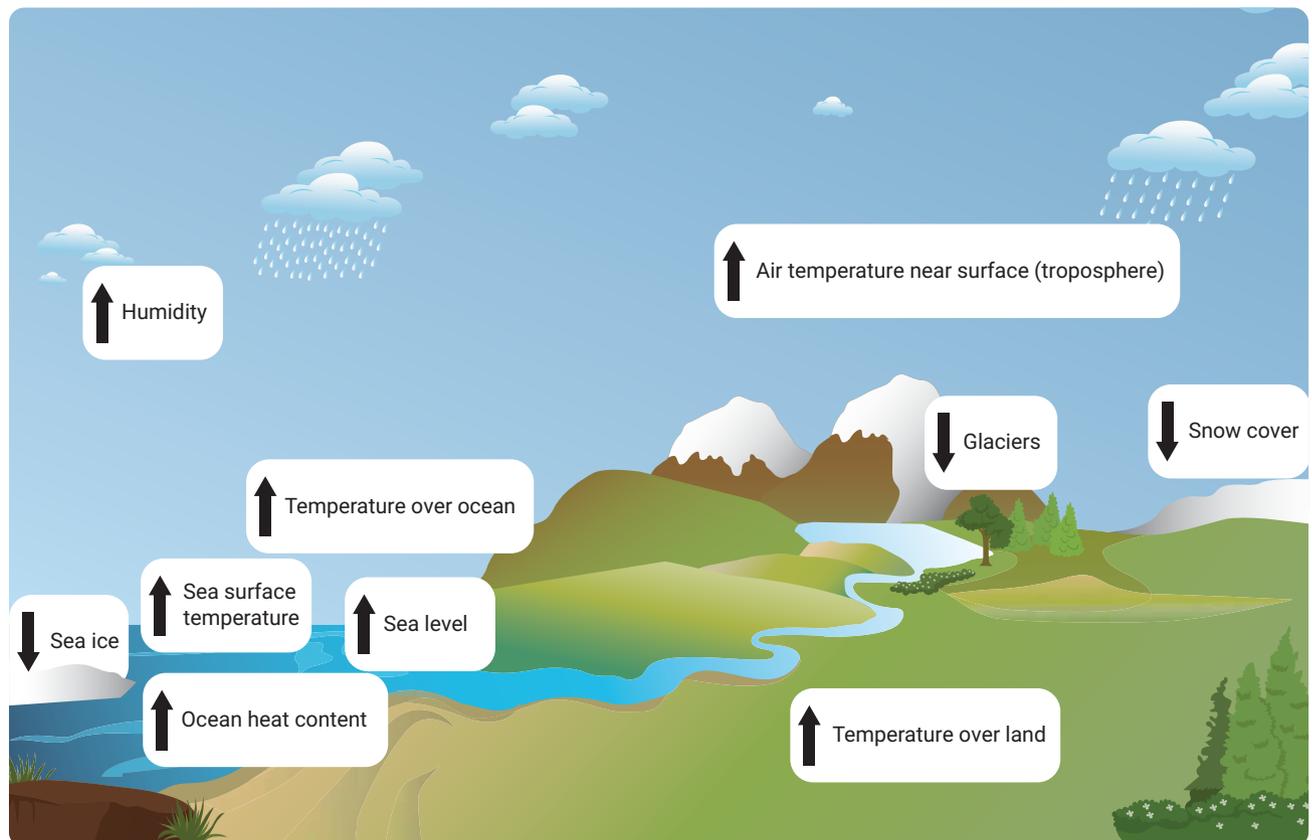
Pseudoscience refers to beliefs or practices that claim to be scientific but have not been supported by fair tests. Experiments testing pseudoscience ideas either fail to provide supporting evidence or yield results that cannot be reproduced. Pseudoscience often produces questions that are not testable. For example, ‘What makes people grow best?’ is not testable because it is too general (it involves many variables rather than a single variable) and ‘best’ is not measurable.

Astrology and phrenology are examples of pseudoscience. Astrology is a set of beliefs linking movements of planets to events on Earth or human traits. Phrenology was the study of the shape of the skull and its supposed link to such things as intelligence and personal traits. Both astrology and phrenology are not supported by scientific evidence.

Many of the arguments or data used as evidence to deny climate change are also pseudoscience. **Climate change denial** refers to theories that propose there is no such thing as climate change that is caused by humans. Some of these theories deny that climate change is happening. Others propose that human activity has nothing to do with a changing climate. However, scientists know that the climate is changing due to human activity because they have strong evidence of many different outcomes of global warming (Figure 2.4.3). Almost all researchers who study the climate and publish their work in respected journals agree that human activities are contributing to a warming planet.

pseudoscience
ideas or practices that claim to be scientific but do not have scientific evidence to back them

climate change denial
theories that deny humans are causing climate change

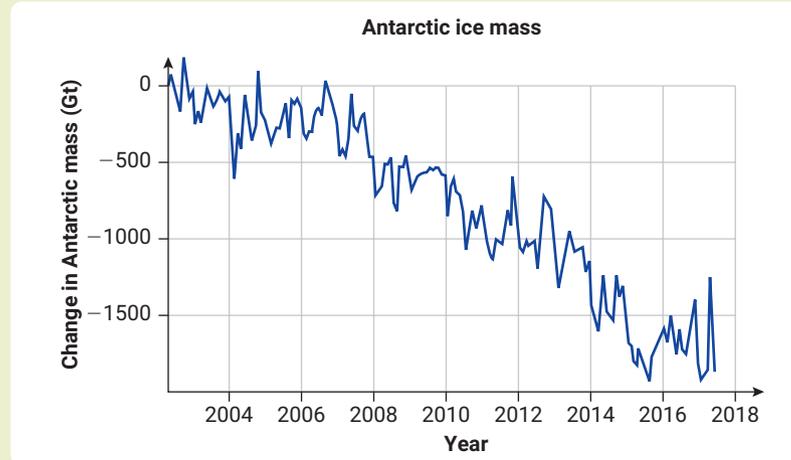


▲ FIGURE 2.4.3 Scientists have identified many different types of evidence that our climate is warming.

☆ ACTIVITY

Interpreting climate data

Look at Figure 2.4.4, which shows how the mass of ice in Antarctica has changed in recent years. The data in the graph was collected by satellites that monitor the thickness, mass and extent of ice. Satellites have been monitoring Antarctica since the 1970s.



▲ FIGURE 2.4.4 Recent changes in Antarctic ice. One gigatonne (1Gt) is 1000 million tonnes. Negative mass values indicate ice loss.

- 1 Describe the trend shown in the graph.
- 2 Is the line of best fit for the data a straight line or a curve?
- 3 What is an inference you could make about declining ice in Antarctica and climate change?
- 4 Suggest where the water from the melted ice has gone. How could you verify your prediction?

Sources and uses of scientific data

There is a wide range of data used in scientific investigations. Data ranges from simple observations using our senses to huge amounts of data collected by satellites. For example, the Landsat 8 satellite launched in 2013 observes Earth by taking continuous images using a range of sensors. The satellite broadcasts these images as hundreds of millions of bits of data per second. Scientists use data from Landsat 8 to monitor changes on Earth due to human activity and natural processes.

All scientific data is collected in a systematic way and can be reproduced using the same methods of collection.

We will cover data collection, data analysis and modelling in Modules 2.6 to 2.10.

2.4 LEARNING CHECK

- 1 **List** three features of scientific data.
- 2 **Define** pseudoscience.
- 3 **Describe** the process of peer review.
- 4 How is scientific data and knowledge different from ideas and data generated in a non-scientific way?
- 5 **Explain** how a series of pencil length measurements can be scientific data.

2.5 Secondary data

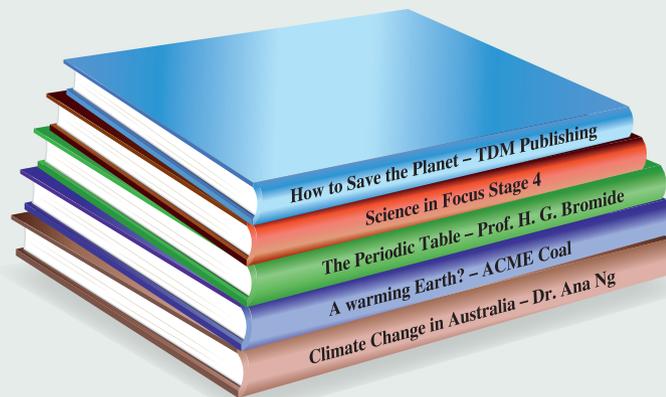
2.5

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ list sources of secondary data
- ✓ describe benefits and potential problems in using secondary data
- ✓ define big data.

GET THINKING

Look at Figure 2.5.1. Where could the information in these books come from? Why do we trust such information? Write down reasons why you might have more (or less) confidence in data you collect than in data collected by others.



▲ FIGURE 2.5.1 Where did the information in these books come from?

primary data

data collected by you; also called 'first-hand' data

secondary data

data that has been collected by someone else

secondary source

a publication, information or data that has been written or collected by another person

What is secondary data?

The data you collect during an investigation is **primary data**. **Secondary data** is data that has been collected by someone else. For example, if you look up information on the melting point of an element or the habitat of koalas, you are working with secondary data. We can describe any data or information written by another person as a **secondary source**.

There are many sources of secondary data, including science reports, articles, textbooks, websites, photos, podcasts and videos. Online databases can contain huge amounts of information. The Pangaea Data publisher website, for example, hosts thousands of sets of data about Earth and the environment. NASA hosts many datasets about space.

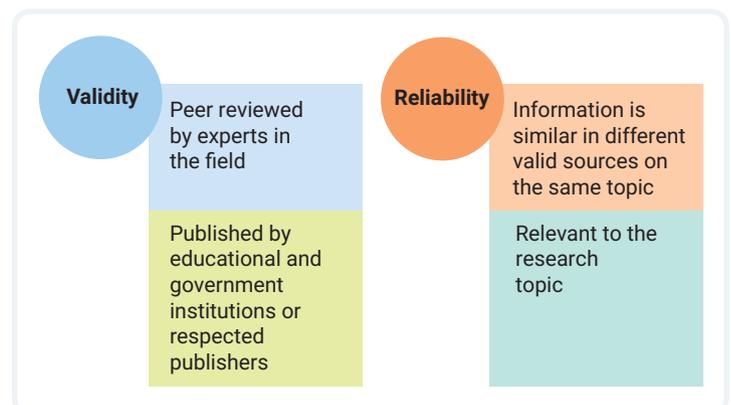
Many Australian and international research organisations share their data with the public on the internet. For example, CERN (the European Council for Nuclear Research), CSIRO (Commonwealth Scientific and Industrial Research Organisation) and the Bureau of Meteorology all publish large amounts of data.

Validity and reliability of secondary sources

Not all secondary sources are of the same quality. Before we use secondary data, we need to determine the **validity** and **reliability** of the source. Figure 2.5.2 shows the things you should think about before you use data from a secondary source.



Weblinks
PANGAEA® Data Publisher
NASA data
CSIRO data
Bureau of Meteorology data
CERN data



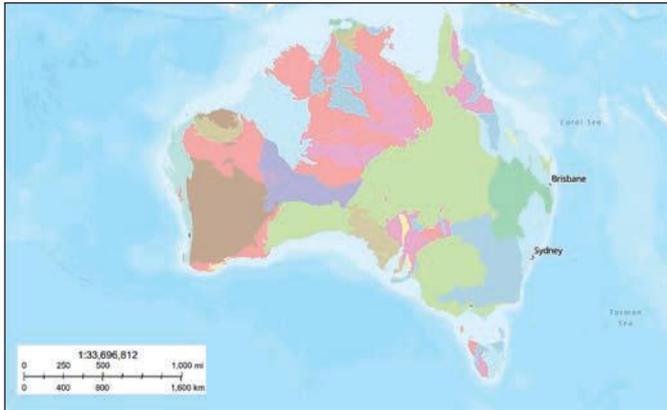
▲ FIGURE 2.5.2 The main things to check when determining the validity and reliability of secondary sources

☆ **ACTIVITY**

Maps as secondary sources

Maps are often compiled from large amounts of primary data. One example is a geological map (Figure 2.5.3), used in Earth science.

- 1 Locate a geological map of your local area. A good place to start is the Geoscience Australia Portal.
- 2 Identify the age range of rocks in your area.
- 3 Make a list of five types of information shown on the map.
- 4 Research how scientists collect information to create a geological map.



Key	Era	Span of time (Ma)
Yellow	Cenozoic	66–0 Ma
Light Green	Mesozoic to Cenozoic	252–0 Ma
Green	Mesozoic	252–66 Ma
Light Blue	Paleozoic to Cenozoic	541–0 Ma
Blue	Paleozoic to Mesozoic	541–66 Ma
Dark Blue	Paleozoic	541–252 Ma
Purple	Proterozoic to Mesozoic	2500–66 Ma
Pink	Proterozoic to Paleozoic	2500–252 Ma
Red	Proterozoic	2500–541 Ma
Light Brown	Archean to Proterozoic	4000–2800 Ma
Dark Brown	Archean	4000–2500 Ma

▲ **FIGURE 2.5.3** A geological map of Australia



Weblink
Geoscience
Australia Portal

Video activity
Big data and SKA

Video
Science skills in a
minute: Secondary
sources

**Science skills
resource**
Science skills in
practice: Evaluating
secondary sources

raw data
data that has not been
processed or analysed

big data
large, complex datasets
that are difficult to
process and analyse

Advantages and disadvantages of secondary data

Using secondary data in science investigations has advantages and disadvantages (Table 2.5.1).

▼ **TABLE 2.5.1** Some of the advantages and disadvantages of using secondary data

Advantages of secondary data	Disadvantages of secondary data
<ul style="list-style-type: none"> • It saves you time because the data is already collected. • It gives you something to compare with your primary data. • It provides information that you could not collect on your own. 	<ul style="list-style-type: none"> • You might not know all the details of how the data was collected. • The data might be out of date. • There could be more relevant or better data to use.

Big datasets

Data scientists are specialists, trained in the use of mathematics, computing and scientific methods, who analyse and interpret data. They do this by processing and analysing **raw data** and data processed by others. Most of the raw data they use is secondary data. Data scientists help people and organisations make decisions.

Many organisations need data scientists to work on the enormous amounts of data that is generated by digital systems and businesses. In many cases, datasets are so large that it's difficult to analyse them by traditional methods. Large, hard-to-manage datasets are referred to as **big data**. Data scientists are experts at extracting useful, targeted information from large sets of secondary data. For example, banks use data scientists to analyse customer spending patterns to detect fraud. If an unusual purchase occurs, the bank can let you know that someone else may be using your account.

The field of artificial intelligence (AI) uses very large sets of secondary data and computer science to produce programs and tools that help solve problems. You have probably used tools that are based on AI, such as a chatbot or a text generator tool.

Science research produces large amounts of big data. For example, genomics is the study of **genetic material** from people and other living things. Genomics has many applications, including the ability to create targeted treatments for diseases that people **inherit**. Each year, genomics data increases at a rate equal to about 40 times that of the entire YouTube platform.

genetic material
the information inside a cell that contains instructions for the development, maintenance and reproduction of living things

inherit
acquire traits from the genetic material passed down from parents

Using secondary data

Herbariums are places that store plant specimens (Figure 2.5.4). The New South Wales Herbarium at Mount Annan stores about 1.4 million specimens. Herbariums use their collections to document plant diversity in different areas. Herbariums are an important resource for identifying known and new species. The scientists at herbariums can determine flowering times and the habitats of species. All these things help in the conservation of natural ecosystems.

- 1 Research images of herbarium plant labels to identify the types of information they include.
- 2 For each type of information you have identified, describe a possible use of the information by other scientists.
- 3 How would you classify the data of a herbarium specimen? Is it a primary or secondary source of data? Does it provide qualitative or quantitative information?

☆ ACTIVITY



▲ FIGURE 2.5.4 A herbarium specimen records the typical features of a plant species.

2.5 LEARNING CHECK

- 1 **Define** secondary data.
- 2 **Describe** three types of secondary data you might use in your investigations.
- 3 **Define** big data.
- 4 Why are specialists such as data scientists required to deal with large volumes of secondary data?
- 5 **Compare** and **contrast** the advantages and disadvantages of primary and secondary data.

2.6 Collecting data

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ identify sources of data used in science and other areas of inquiry
- ✓ identify problems and strategies to solve problems during the planning and collection of data.



GET THINKING

Imagine you have been asked to research the blue-faced honeyeater (Figure 2.6.1).

What secondary data would you collect on the bird? How many sources would you use? How would the data you collect be different if you conducted a survey of blue-faced honeyeater numbers in a national park? Make a table of the different types of information you might collect.



Dirk Kotze/Shutterstock.com

▲ **FIGURE 2.6.1** The blue-faced honeyeater (*Entomyzon cyanotis*)

Planning data collection

Planning how you will collect your data is key to gathering good quality data. Poor planning can lead to insufficient data, the wrong type of data, the wrong conclusions and wasted resources. Table 2.6.1 outlines the key questions you need to ask when you plan your data collection and why those questions are important. Remember that the goal of a good investigation is to be a fair test.

▼ **TABLE 2.6.1** Questions to ask before collecting data in investigations

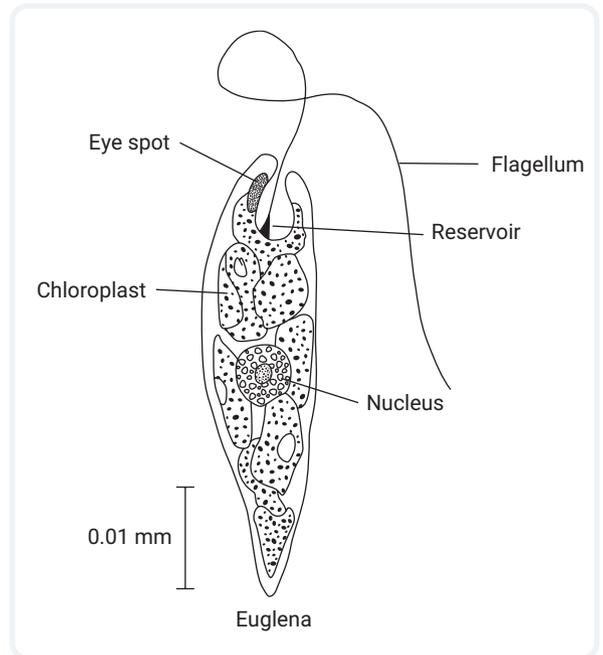
Key question	Additional points for quantitative data collection	Additional points for qualitative data collection
What is the purpose of the research?	A clear purpose helps to identify relevant and irrelevant information.	
What is my hypothesis?	A hypothesis identifies the sorts of information needed for a fair test.	
Data collection: <ul style="list-style-type: none"> • what type of data? • how much data? • which units of measurement are appropriate (if any)? • which instrument is best (if applicable)? 	<ul style="list-style-type: none"> • Choose appropriate instruments to collect quantitative data • Decide how many measurements are needed to reduce errors • Too much information is a waste of resources. • Does the environment affect the instrument? E.g. Does air temperature, air pressure or light level need to be measured? 	<ul style="list-style-type: none"> • Qualitative data involves collecting objects or making observations. • You could use secondary sources to collect information. • How much information do you need to make confident conclusions?
What are the best procedures for collecting, processing and storing the data?	<ul style="list-style-type: none"> • Is a controlled experiment needed to collect quantitative data? • Table design helps decide how much data needs to be collected and how it will be organised for analysis. 	<ul style="list-style-type: none"> • Qualitative data will be summarised during analysis. How will the analysis work? What sorts of features will data collection need to focus on?

Collecting and recording data

An important part of collecting good data is a clear and detailed procedure. Sometimes scientists collect data individually or as part of a small laboratory group. In other investigations, several laboratory groups work on the same or different parts of an investigation. In both cases, scientists closely follow a clear procedure to ensure everyone is doing the same thing. This is the best way to get good, **replicable** data.

Recording data systematically is also important because it adds to the reliability of an investigation and helps to make the investigation repeatable. When you record quantitative data, you need to record units of measurements and any observations of things that might affect the outcome of an investigation. Using tables makes it easier to accurately record your data. In investigations using secondary source data, it is important to record sources in a consistent way.

If you are recording data as a diagram, use labels, titles and a key if symbols are used (Figure 2.6.2).



▲ **FIGURE 2.6.2** Scientific diagrams are another way to summarise data. This is an image of an organism in pond water viewed through a microscope.

Checking validity, reliability and accuracy during data collection

In Chapter 1, you learned about the importance of validity, reliability and accuracy of scientific investigations to ensure a fair test. You also need to consider these things when you are planning and collecting your data. This is also true when using data from secondary sources.

Table 2.6.2 lists the questions you can use to check validity, reliability and accuracy as you collect or choose your data.

replicable

something that can be reproduced or copied exactly

outlier

a value that differs significantly from other values in a dataset

bias

a strong preference for one thing or idea over another

▼ **TABLE 2.6.2** How to check for validity, reliability and accuracy in data

Feature	Primary sources of data	Secondary sources of data
Validity – how well does the investigation test the hypothesis?	<ul style="list-style-type: none"> Are you collecting data on one variable while you change another variable? Have you controlled all other variables that may affect the dependent variable? Have you recorded data on the controlled variables? Have you recorded how you are minimising possible sources of error? 	<ul style="list-style-type: none"> Is the data relevant to the question you're asking? Is the information up to date? Is the information published by a person/source with a good reputation? Is the author qualified in the area they describe or explain? Does the information explain or present different points of view?
Reliability – how similar is the data from repeated experiments?	<ul style="list-style-type: none"> Are you collecting enough data to reduce errors and outliers? 	<ul style="list-style-type: none"> Do your sources provide consistent information? Are you recording the data from the source(s) in a systematic way?
Accuracy – how close is a measurement to the true value?	<ul style="list-style-type: none"> Do you know the true value you are aiming for? 	<ul style="list-style-type: none"> Is the information in the source free of bias?

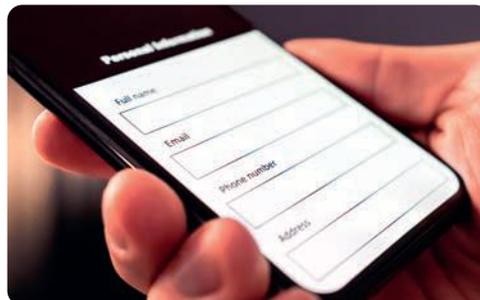
Data privacy

privacy

the right to be free from public attention

When you collect information from people by surveys or interviews, it is important to think about the **privacy** of the data. Protecting people's right to privacy means you need to think about how a person might be identified from their responses (Figure 2.6.3). Some ways to help protect people's privacy are:

- not using names in a report
- combining data so it's harder to link responses to individual people
- not sharing personal information
- only collecting the information you really need
- not collecting contact details such as emails, phone numbers or addresses.



Tero Vesalainen/Shutterstock.com

▲ FIGURE 2.6.3 It is important to think about privacy when collecting qualitative data from people.

☆ ACTIVITY

Collecting data on school waste

In this activity, you will plan how to collect data to help improve waste management in your school or reduce waste production.

- 1 Brainstorm the possible categories of waste produced at your school and identify who generates it (students, teaching staff, administrative staff etc.).
- 2 For each category of waste, decide how to collect data. Here are some important questions to consider:
 - a Will all the data be quantitative?
 - b What types of qualitative data could you collect?
 - c At what time of day should you measure it?
 - d How many times a week should you measure it?
 - e Should you check every waste bin, or can you sample them?
 - f How many people do you need to collect the data?
- 3 Decide how you will analyse the data. What will the data tables look like? Will you graph your results? If so, how?
- 4 Assess your plan. Does it seem manageable? Will the data be reliable? If you find problems in the plan, how might the plan be adapted to make it better?

2.6 LEARNING CHECK

- 1 **Identify** the main outcomes of poorly planned data collection.
- 2 **Describe** the importance of choosing the right amount of data to collect.
- 3 **Describe** some differences in how you collect primary and secondary data.
- 4 **Describe** two ways you can protect people's privacy when collecting qualitative data.
- 5 **Explain** why it is important to protect people's privacy.
- 6 **Explain** why it is important to consider validity, reliability and accuracy when you are planning and collecting data in a science investigation.

**BY THE END OF
THIS MODULE, YOU
WILL BE ABLE TO:**

- ✓ follow a planned procedure to undertake valid and reliable investigations using data
- ✓ use a variety of ways to process and represent data.

GET THINKING

Research on aircraft engines requires careful and accurate analysis (Figure 2.7.1). The lives of pilots, cabin crew and passengers depend on the engine working well. How do scientists and engineers make sense of data? How might they recognise patterns or faults in data? Make a list of features in data that gives you confidence that the data has been well measured.



▲ FIGURE 2.7.1 Engineers research aircraft design to ensure safety and reliability.



**Maths in science
video**
Mean, median and mode

Video
Science skills in a minute: Collecting and organising data

**Science skills
resource**
Science skills in practice: Collecting and organising data

Interactive resource
Drag and drop: Statistics

Steps of data analysis

Scientists analyse a dataset to find something new or to test a hypothesis. We analyse the data for the same purpose in our own science investigations. To achieve this goal, we work to identify trends, patterns and relationships in the data.

You can divide data analysis into several stages (Table 2.7.1). There are similarities between how we work in a science laboratory and the **workflow** of data scientists. In this module we will focus on what data scientists describe as ‘cleaning data’ and ‘exploring data’. In Module 2.8, we’ll look at visualising and modelling the data.

workflow

the sequence of tasks used in the processing of data or the creation of something from raw materials

▼ TABLE 2.7.1 Similarities between science investigations and work stages in a data science workflow

	The stages of a science investigation	The stages of a data science workflow
1	Propose a question or hypothesis.	Ask an interesting question.
2	Make observations, conduct a controlled experiment to collect primary data or collect secondary data.	Obtain the data.
3	Organise the data.	Clean the data.
4	Summarise the data and graph it.	Explore the data.
5	Identify relationships such as trends, patterns or grouping in the data.	Model the data.
6	Interpret the identified relationships and how they relate to the question or hypothesis. Review the validity and reliability of the data.	Reflect on the findings.
7	Report the investigation (method, results and interpretation).	Communicate the results.

Data preparation and cleaning

Analysis should begin with well-organised and accurate data. Ensure your data is in an effective table. If you transfer data to a computer or spreadsheet, check you have copied the information correctly.

Sometimes you will need to edit a table before you can analyse it. The tidying of data is called **data cleaning**. Data cleaning involves:

- checking column headings are correct
- ensuring units are present
- removing outliers if they are clearly due to a measuring error
- identifying missing data.

data cleaning

the process of fixing errors and other problems in datasets

Exploring the data: statistics

The second stage of data analysis is exploring the data. Data scientists use two main approaches to identify trends and patterns: statistics and data visualisation.

Statistics are summaries of datasets. We use statistics to describe three main features of a dataset:

- extreme values
- the centre of a sample of measurements
- the spread of values in a sample.

Table 2.7.2 describes the statistics we can use to explore the data and shows how to find the mean, median and range of a dataset.

▼ TABLE 2.7.2 Basic statistics for summarising datasets

Measurement type	Statistic	Definition or calculation	Example, using the dataset 2, 7, 3, 5, 8
Extreme values	Maximum	Largest value	8
	Minimum	Smallest value	2
Centre value	Average or mean	Sum of values divided by number of values	$\frac{2 + 7 + 3 + 5 + 8}{5} = 5$
	Median	Centre value in an ordered dataset	2, 3, 5, 7, 8, so median is 5
Spread of values	Range	Maximum value minus minimum value	$8 - 2 = 6$

mean

the calculated 'central' value of a set of numbers; an average

median

the middle of an ordered set of numbers

range

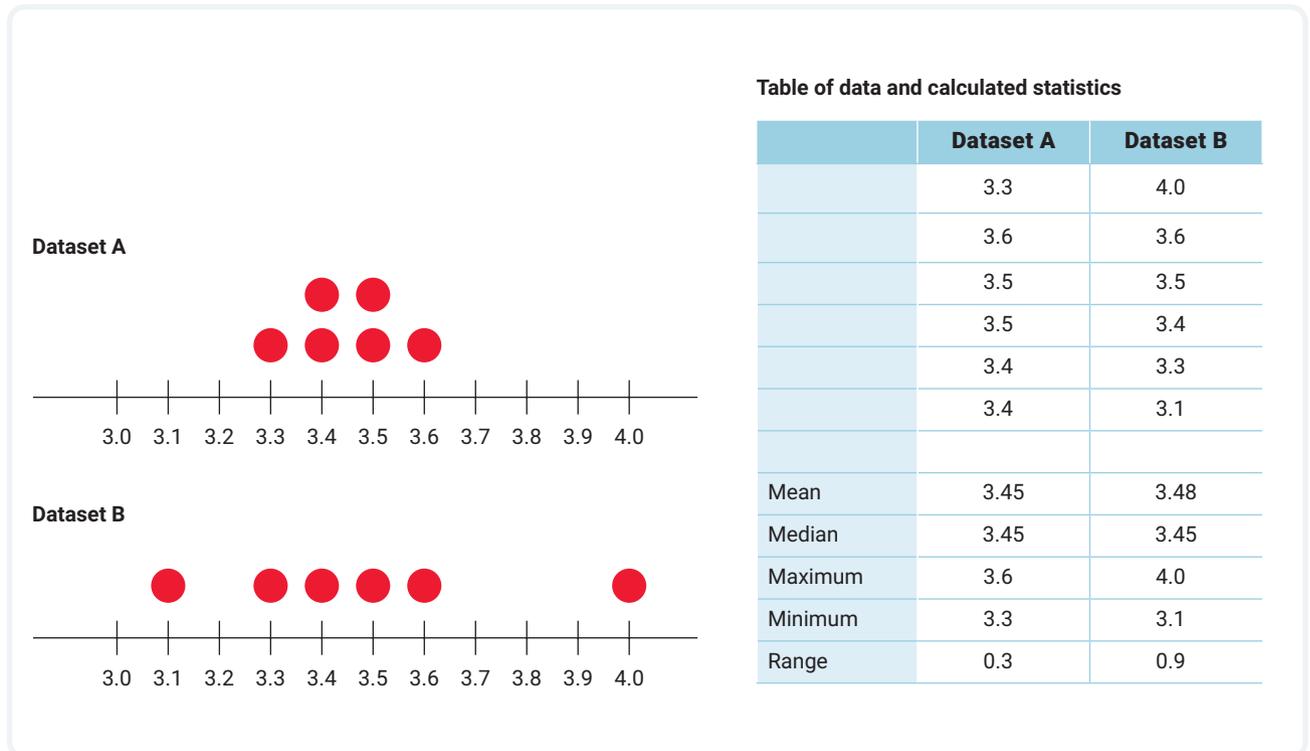
a measure of spread calculated by subtracting the smallest number from the largest number in a dataset

Statistics help us understand the distribution of measurements. For example, Figure 2.7.2 shows two datasets. For each dataset, the simple graph represents the distribution of data points and the table shows the statistics calculated. Dataset A in Figure 2.7.2 has the same mean and median because the data is evenly distributed around the mean. Dataset B has a larger spread of values and the mean is larger than the median because the spread of values is uneven.



Extra activity
Playing with python

You can see dataset B has a value on the far right of the graph, away from the other data points. This is known as an outlier. Sometimes outliers are due to mistakes in how you measured the data. But occasionally outliers will accurately record extreme values of what you are measuring.



▲ FIGURE 2.7.2 A comparison of two data samples: dataset A and dataset B

Exploring the data: data visualisation

Data visualisation is the representation of data in the form of graphs, diagrams or pictures. By presenting data from tables in one or more graphs, it is easier to identify trends, **clusters** and patterns. You will learn more about data visualisation in Module 2.8.

cluster

a group of data points that are closer to each other than to other data points in a dataset

2.7 LEARNING CHECK

- 1 **Describe** the purpose of data analysis.
- 2 **Define** data cleaning.
- 3 **Compare** mean and range.
- 4 A student measured the temperatures of five hot 30-gram soil samples from a kiln: 82°C, 86°C, 85°C, 86°C, 89°C.
 - a **Calculate** the mean and median for the temperatures.
 - b **Calculate** the range of the temperatures.
- 5 **Describe** the purpose of exploring data using data visualisation.

2.8

Analysing datasets: trends and correlations

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ use a variety of ways to process and represent data
- ✓ use data to identify trends, patterns and relationships, and to draw conclusions.



Maths in science videos

Correlation and causation

Distorted graphs

Quiz

Analysing data

Extra activities

Working with spreadsheets

Analysing clusters

GET THINKING

A student measures the temperature of water as it is heated from 20°C until it boils at 99°C. The student wonders if the thermometer is accurate. Should they make more measurements? Another student suggests they use the data they have. What should the student do? How can you use graphs to produce confident predictions and identify relationships between variables? Make a concept map of your ideas about graphs and how you can use them to make predictions and identify relationships.



nuwatchai sirkrungplee/Shutterstock.com

▲ FIGURE 2.8.1 Measuring water temperature with a thermometer

Correlations

trend

the general pattern or direction of data

correlation

a trend in data in which one variable changes consistently as the other variable changes

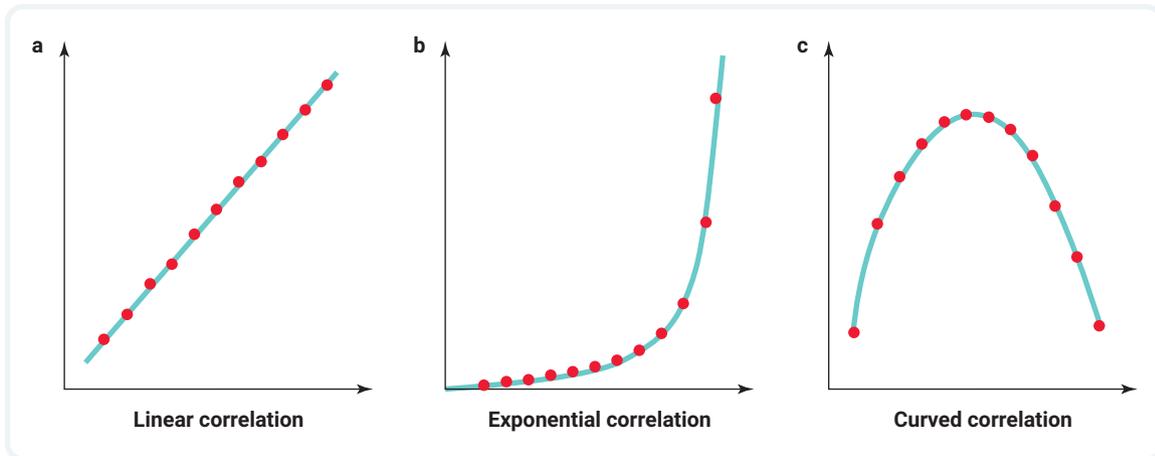
A **trend** is a general change in one variable as another variable changes. It is important that you learn to identify trends, because they describe how variables change together. The **correlation** is the closeness of the relationship between two variables. The way the two variables change in relation to each other isn't always the same. We can classify the relationships into three types of correlation.

Types of correlation

If the data points seem to cluster along a straight line, the pattern is called a linear correlation (Figure 2.8.2a). An example of a linear correlation is the volume button and the loudness of your phone's notification tone. The more you press the '+' button, the louder the volume of your notification.

Sometimes, changes do not occur in equal increments and there can be a rapid increase or decrease in the rate of change. This is known as exponential correlation (Figure 2.8.2b). For example, bread can quickly go from having no mould to being covered in mould. Therefore, the rate of change in the mould growth over time is not consistent.

Sometimes a dependent variable rises and falls, creating a curved correlation (Figure 2.8.2c). The temperature of water left outside for many hours is likely to increase during the day and then decrease at night. Graphing this data would show you curved correlation between the variables of temperature and time.



▲ FIGURE 2.8.2 Three types of correlation: (a) linear, (b) exponential and (c) curved

Types of linear correlation

Linear correlations may show one variable increasing as the other variable increases. In other words, the two variables are moving together in the same direction. This is called **positive correlation** (Figure 2.8.3a). An example of positive correlation is the longer a beaker of water is over a Bunsen flame, the hotter the water becomes.

If one variable increases as the other variable decreases (the variables are moving in the opposite direction), we describe the relationship as a **negative correlation** (Figure 2.8.3b). An example of negative correlation is the more it rains, the less often you need to water the garden.

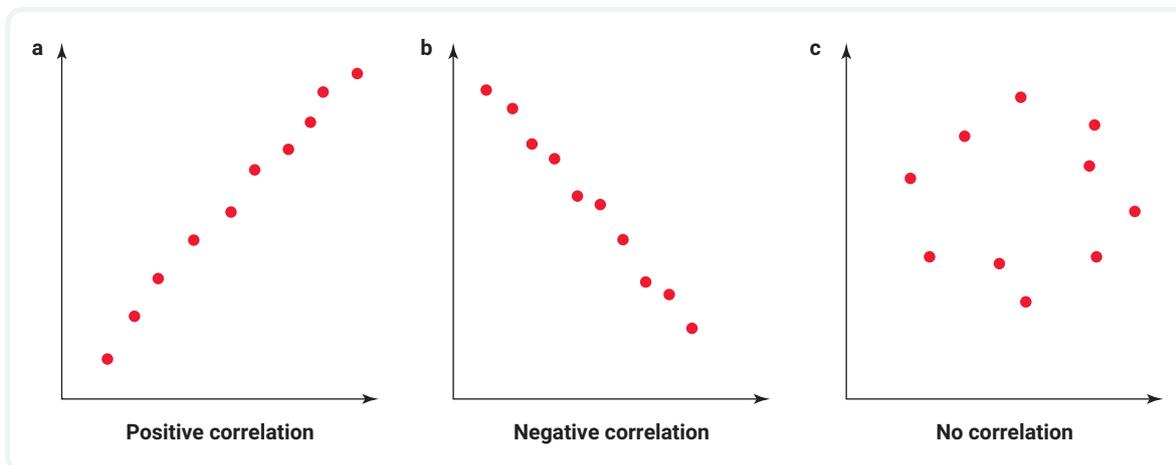
If the best line of fit is a horizontal or vertical line, we say there is no correlation. As one of the variables changes, the other remains the same or changes in an unpredictable way (Figure 2.8.3c), meaning there is no relationship between the two variables.

positive correlation

a correlation where one variable increases as the other variable increases

negative correlation

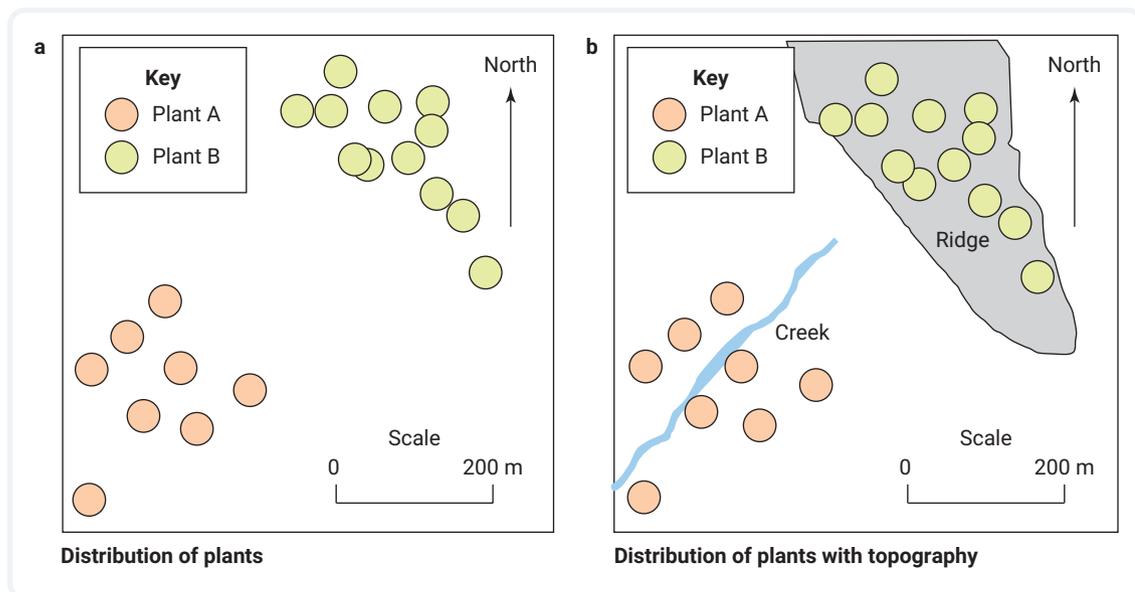
a correlation where one variable decreases as the other variable increases



▲ FIGURE 2.8.3 Linear correlation can be (a) positive or (b) negative. (c) Two variables may show no correlation.

Patterns in distributions

Sometimes a graph of data will not show a linear relationship but there may be groupings of data points that suggest a relationship (Figure 2.8.4a). There may be other factors affecting the distribution of data points and additional information may allow you to make predictions about the reasons for the distribution (Figure 2.8.4b).



▲ FIGURE 2.8.4 (a) The distribution of plants alone does not help to identify why they are located where they are. (b) Additional information, such as topography, helps to show the links between distribution and plant needs or adaptations.

Modelling relationships with a line of best fit

line of best fit
the line that best represents the trend of a set of data points

When we identify a correlation, it is usual to add a **line of best fit** to the data. It is the line that best represents the trend of the data points. The key points to remember about lines of best fit are:

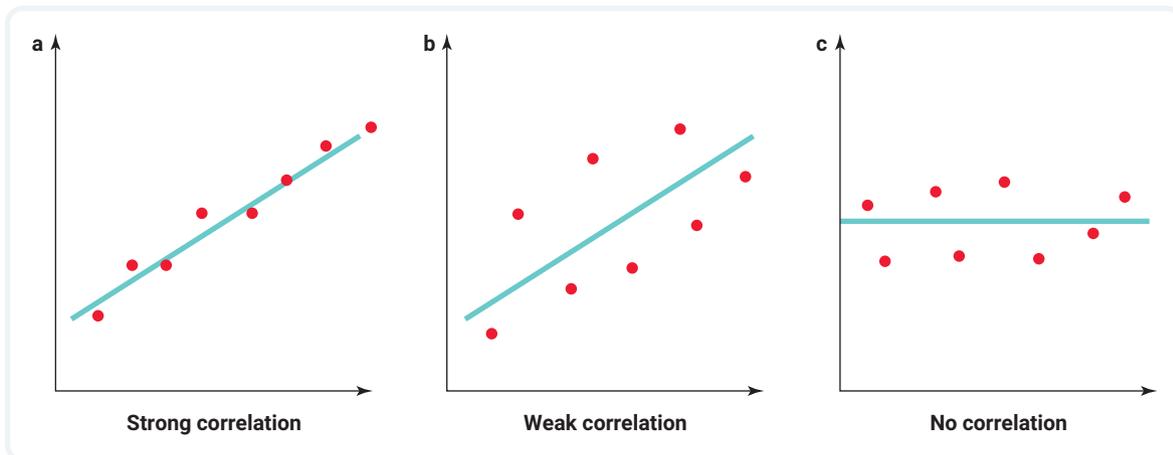
- a line of best fit is a model. It suggests where the data would plot if the relationship is perfect
- we use the line of best fit to describe the trend and relationship
- a line of best fit is placed so that the vertical distance between it and the data points is kept to a minimum.

Lines of best fit are usually calculated mathematically. However, for now, you will be drawing lines of best fit by eye.

Correlation and random error

Correlations are easier to recognise when the random errors of data are small. **Random errors** are small errors caused by slight variations in the instrument or environment that do not produce the same error every time. Consider a linear relationship between two variables shown in Figure 2.8.5. If data points seem to lie very close to, or on, a line of best fit, the correlation is described as a strong correlation (Figure 2.8.5a). If the random errors are large, or if we have not properly controlled a variable, the data points plot away from the line of best fit. We describe this as a weak correlation (Figure 2.8.5b). If there is no obvious pattern, we say that there is no correlation between the variables.

random error
a small, variable error caused by slight variations in an instrument or the environment



▲ FIGURE 2.8.5 The degree of correlation can be (a) strong or (b) weak, or (c) there can be no correlation.

Drawing conclusions from correlations

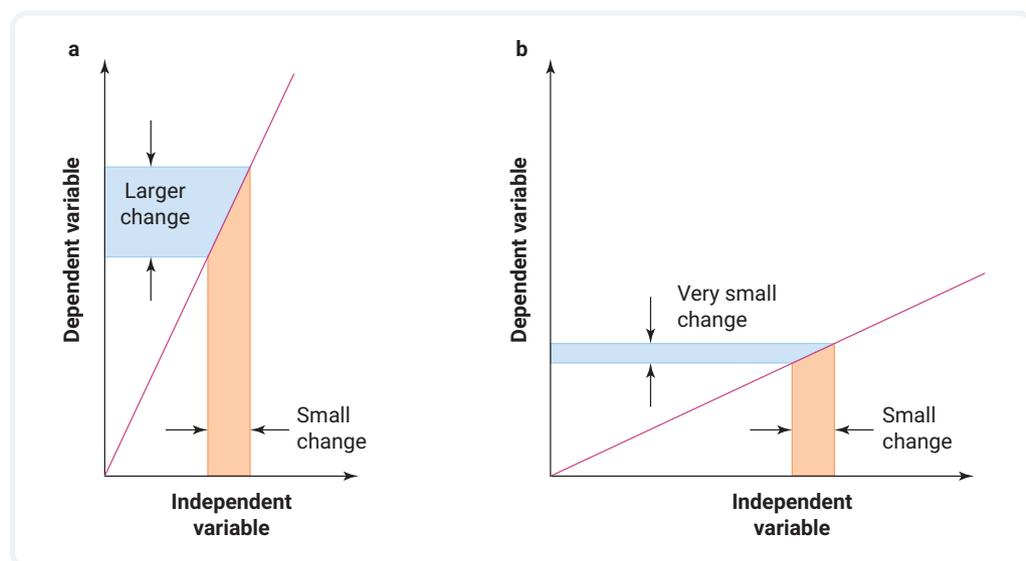
Drawing conclusions from correlations, particularly weak correlations, can lead to mistakes and wrong interpretations. Module 1.12 introduced you to the concepts of correlation and causation. Remember that correlation does not always mean causation. Sometimes the change in one variable has nothing to do with the other variable.

A clear, but weak, correlation in an investigation provides ideas for further research. Were there any errors? And can you reduce these errors? Is there another factor involved in the relationship between the correlated variables?

Sometimes repeating an investigation will help you identify improvements or a better way of conducting the investigation. You might need to do further research to understand what is affecting the line of best fit.

Using the line of best fit for conclusions and predictions

The slope of the line of best fit describes how rapidly the dependent variable changes as the independent variable is changed. A steep slope indicates rapid change (Figure 2.8.6a) and a shallow slope means a slow change (Figure 2.8.6b). These factors help us describe the relationship between the variables we are studying. A strong correlation helps to support the conclusions we make about the relationship.



▲ FIGURE 2.8.6 (a) A steep line of best fit means that a small change in the independent variable causes a large change in the dependent variable. (b) When the line of best fit has a shallow slope, the same change in the independent variable results in only a small change in the dependent variable.

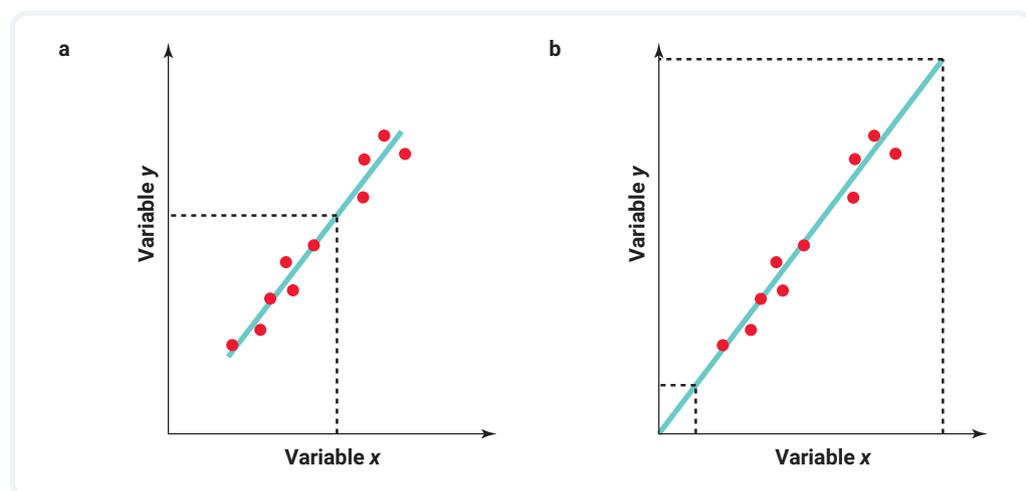
interpolation

the estimation of an unknown value within the range of known data for a relationship

extrapolation

the estimation of an unknown value by extending a trend beyond the known values

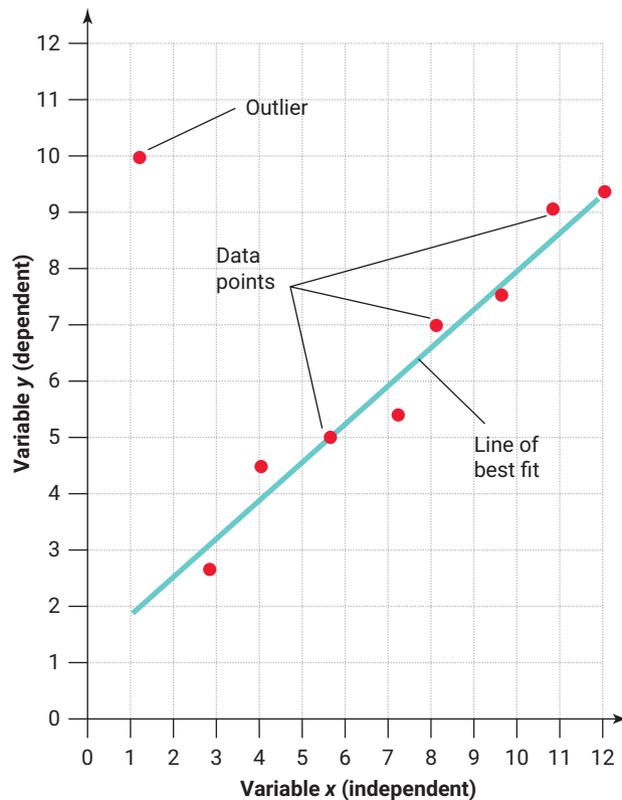
We can also use the line of best fit to make predictions, assuming the line of best fit is correct. If there is a missing measurement in the range of values covered by the data, you can use the line of best fit to predict what that value is. This is called **interpolation** (Figure 2.8.7a). If you extend the line of best fit beyond the range of your data to make a prediction, it is called **extrapolation** (Figure 2.8.7b). Do not extrapolate data unless you are confident that the trend will continue as it does in the range you have measured.



▲ FIGURE 2.8.7 (a) Interpolation means using values of x to predict values of y within the range of known data; (b) extrapolation means using values of x to predict values of y outside the range of known data.

2.8 LEARNING CHECK

- 1 **Define** line of best fit.
- 2 **Describe** the meaning of the slope of a line of best fit.
- 3 **Explain** why graphing data is an important part of data analysis.
- 4 Are strong correlations always caused by one variable influencing another?
- 5 **Apply** your understanding of correlation to the following scenarios and identify which type of correlation is described in each case.
 - a As the temperature outside gets colder, Pedro puts on more layers of clothes.
 - b The hotter it gets, the more ice creams Lulu sells in her shop.
 - c The more people arrive at the restaurant, the noisier it gets.
 - d The more money Sara spends, the less she has in her bank account.
 - e Ten students in class 7C have black hair. All 28 students in 7C love Science.
 - f A sink full of water empties slowly when the plug is removed.
- 6 Use the graph below to answer the following questions.
 - a **Describe** the correlation shown in the graph.
 - b Why is the data point (1,10) referred to as an outlier?
 - c Which variable was changed by the experimenter in gathering this data?
 - d **Explain** why it is incorrect to say, using this data, that a change in variable x causes a change in variable y .



2.9 Scientific models

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ identify models as a useful scientific problem-solving strategy
- ✓ analyse data and information related to scientific models.



Video activity
Modelling

Extra activity
Chemical models

GET THINKING

Figure 2.9.1 shows a mechanical device called an orrery, a mechanical model of the solar system. What do the gears do? Is the solar system complete? What could we learn from such a complicated device? Make a list of questions you would ask the creator of the orrery.



Dyachenko/Adobe Stock

▲ FIGURE 2.9.1 An orrery – a mechanical model of the solar system

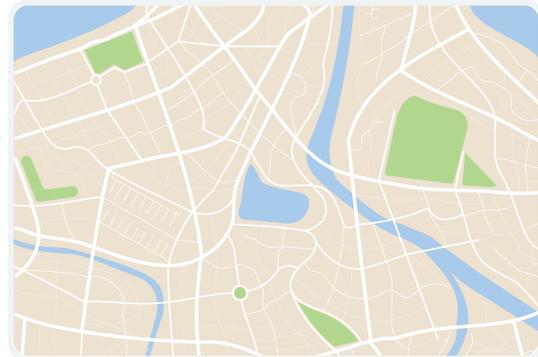
Models and their uses

model

a simplified representation of a process or object

A **model** is a simplified representation of a process or object. A model should always have a clear purpose. The purpose determines what type of information the model should represent, and how complex that information needs to be. You should leave out any details that are not relevant to the purpose of the model.

A map is a good example of a model (Figure 2.9.2). The level of detail in the map depends on the map's purpose. If the map is for drivers, it is likely to leave out scientific information, such as vegetation distribution or geology. But a geological map for use by scientists might leave out towns and roads. A map, like any good model, can be used to make predictions and answer questions. It can also get you thinking about questions for further research, such as 'Why are the green areas distributed in this way'



▲ FIGURE 2.9.2 Maps are a type of model. What features of an area does this map represent?

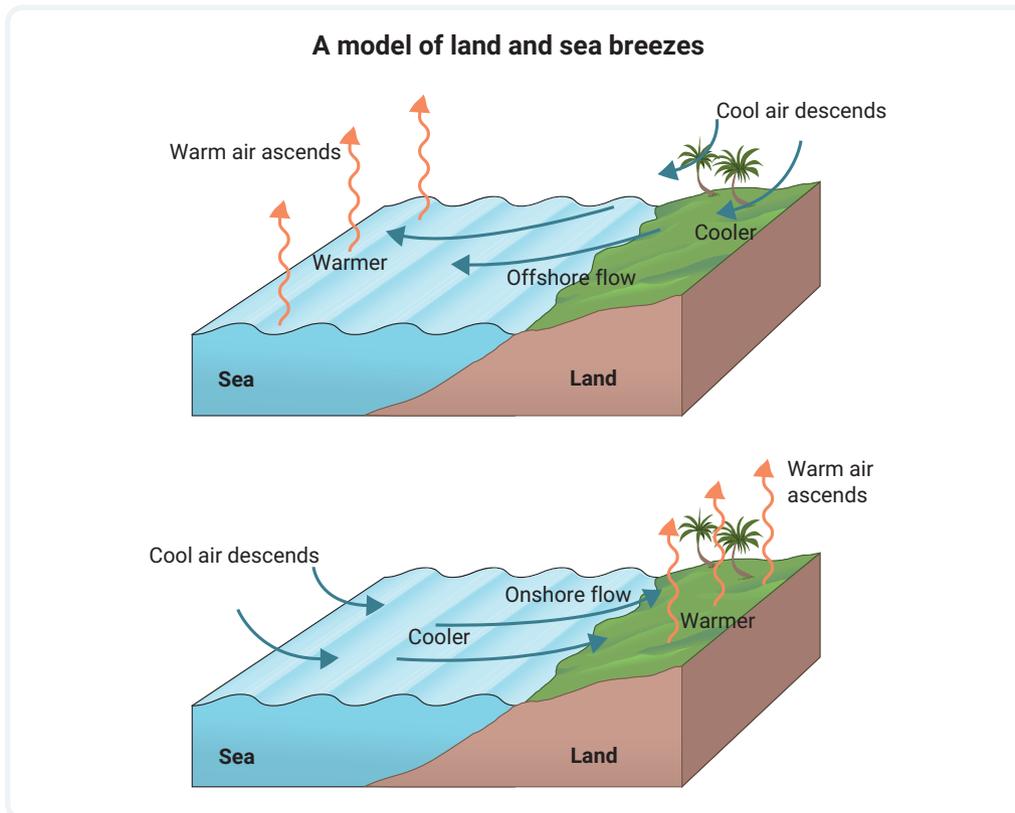
scientific model

a model based on observations and measurements of an object or process

Scientists use **scientific models** to understand processes, make predictions and communicate their ideas. For example, Figure 2.9.3 shows a scientific model explaining how offshore and onshore winds form. Notice how air flows towards a place where warm air rises, from a place where the surface is colder. This model of breeze formation is based on observations of winds along coasts. It shows the process is the same for winds directed towards and away from the coast.

We can use this model to make predictions. For example, we might predict that on summer afternoons when land has warmed more than the ocean, surface onshore breezes will form.

A scientific model is based on observations and measurements of the object or process the model represents. Scientific models represent things that are too difficult or complex to observe directly (Table 2.9.1). For example, we use models of atoms to explain how they behave because atoms are too small to see. We use data from experiments to either support or modify the model. In this way, our confidence in the scientific model grows. Scientists use the plate tectonic model to explain the formation of oceans and mountains, which occurs over millions of years. Thousands of scientists have collected evidence of tectonic movements that support the model and help to refine it.



▲ FIGURE 2.9.3 A scientific conceptual model of how onshore and offshore breezes form

▼ TABLE 2.9.1 Things that scientific models can represent

Models can represent	Examples
Very small things and processes	Cells, atoms, molecules
Very large things and processes	Planets, galaxies, tectonic plates
Events that happen too quickly for us to observe	Chemical reactions, high-speed collisions, causes of earthquakes
Events that happen too slowly for us to observe	Weathering of rocks, formation of mountains, how species change over time
Things that are difficult to visualise	How introduced species change habitats, how diseases spread, the formation of stars
Things that have not happened yet	Weather forecasts, volcanic eruptions, river flooding
Things that no longer exist	Bodies of fossilised organisms, such as dinosaurs
Things that have not been invented yet	Prototypes of cars or aeroplanes, new drugs

Types of models

There are three main types of models: physical, conceptual and mathematical. Because most mathematical modelling occurs on computers, mathematical models are also often called computer models.

Physical models

physical model

a model constructed from physical materials

Physical models are made from materials such as plastic, metal, wood or plasticine. Physical models can show us how parts relate to each other. For example, a model of body systems helps us understand where the stomach is relative to the liver. Physical models can also show how things appear from different angles. Models of a sphere lit with a lamp, for example, help us understand phases of the Moon. Some physical models have moving parts so we can see how things change over time. The orrery (Figure 2.9.1) is an example of a physical model.

Conceptual models

conceptual model

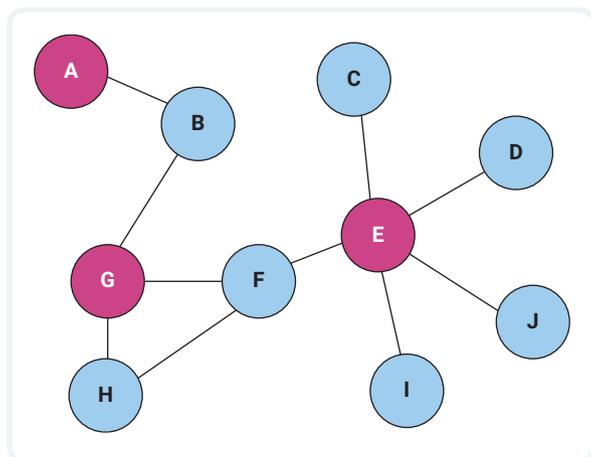
a mental representation of a concept or idea; also called a mental model

Conceptual models or mental models are mental representations of things. Based on evidence, a conceptual model helps us understand relationships and behaviours. The

particle theory of matter is a conceptual model that helps us understand the behaviour of solids, liquids and gases. Atomic models are also conceptual. We cannot observe atoms or their parts, but scientists have used evidence to create a model that generates accurate predictions about atoms and their behaviour.

A third example is a food web diagram. Food webs show the relationships between organisms in a community. We can use them to make predictions about the effects of a species increasing or decreasing in numbers. However, it has limitations, such as not showing the non-living parts of the environment.

A food web is also an example of a **network** diagram (Figure 2.9.4). Scientists model networks to study many things, such as the interactions of chemicals in cells, social networks and computer interconnections.



▲ FIGURE 2.9.4 A network diagram. Circles can represent objects, such as people, chemicals or computers. Lines represent the relationships between the objects, such as friendships, chemical interactions or computer linkage.

network

a group of interconnected people or things

mathematical model

a model that uses mathematical concepts to describe and predict the behaviour of objects or systems

Mathematical or computer models

Mathematical models use maths concepts to describe and predict the behaviour of objects or systems. Some mathematical models can be simple, such as this relationship:

$$\text{speed} = \frac{\text{distance}}{\text{time}} \text{ or, in symbol form, } v = \frac{d}{t}$$

This equation is also a mathematical model. It tells us that an object's speed (how fast it moves) depends on two things: the distance it moves and the time it takes to do so. The equation ignores some things, such as friction and air resistance, but allows simple, useful predictions.

Imagine two cars, A and B. Both travel the same distance, but car B takes twice as long as car A. Which one is fastest? We can make a simple comparison using our model (Table 2.9.2).

▼ TABLE 2.9.2 Modelling car speed

Car	Distance (metres)	Time (s)	Speed (m/s)
A	1000	1000	$v = \frac{d}{t} = \frac{1000}{1000} = 1$
B	1000	2000	$v = \frac{d}{t} = \frac{1000}{2000} = 0.5$

Computer models usually consist of sets of equations with several variables. They allow scientists to **simulate** a wide range of events and processes. Scientists can change variables within the model to see how the outcome changes.

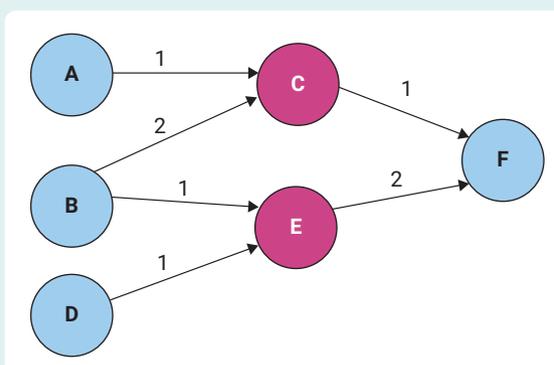
Climate models are large computer models. Many scientists build these models and they can contain hundreds of variables. The models describe the movement of the atmosphere and oceans, seasonal changes, and the flow of water vapour and other gases between the land, oceans and ice. The computer code of such complex models is huge – it would fill about 60 textbooks like the one you are reading now. The computer code runs on large supercomputers capable of tens of thousands of trillions of calculations per second. Scientists use climate models to forecast weather and predict the effects of a warming climate.

simulate
represent different aspects of a phenomenon in a model to make predictions

2.9 LEARNING CHECK

- 1 What is a model?
- 2 **List** four characteristics of a good scientific model.
- 3 **State** three reasons scientist use models.
- 4 **Compare** a physical model and a mathematical model in terms of their uses for making predictions and explaining how something works.
- 5 **Construct** a table listing three types of models with their definitions and two examples of each.

- 6 The network diagram shown here models chemical combinations. Each letter represents a chemical and the numbers represent how much is needed to make a new chemical. For example, to create chemical C, you need one A and two Bs.



- a What sort of model is this?
- b **Describe** how chemical E is created.
- c **Predict** what will happen if only small amounts of B are available.
- d **Explain** why chemical F cannot be created if there is no chemical D.

2.10 Analysing models

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ identify models as a useful scientific problem-solving strategy
- ✓ explain how scientists use data to model and predict phenomena
- ✓ analyse data and information to assess a scientific model.



Maths in science video
Analysing different graphs

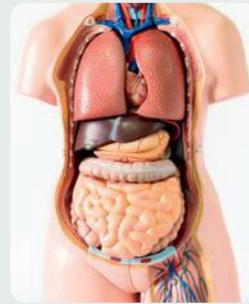
Interactive resources

Simulation:
Pendulum lab

Crossword:
Data science

GET THINKING

Many scientists use models to solve problems. But all models have strengths and weaknesses. Figure 2.10.1 shows a model of body systems. Such models help students understand anatomy. Make a list of the strengths of such a model and another list of weaknesses. Can you use your lists to identify the properties of a good model?



◀ **FIGURE 2.10.1**
A model of a human torso

Komsan Loonprom/Shutterstock.com

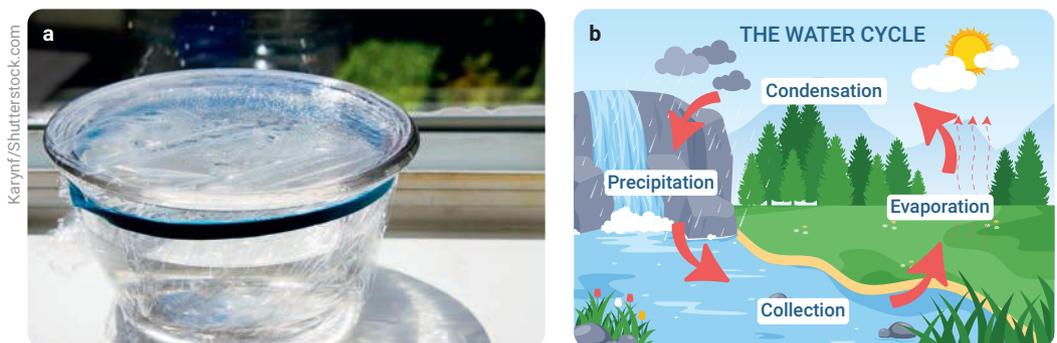
Reasons for analysing models

Scientists analyse models to:

- determine how well the model explains its subject
- modify and improve hypotheses and theories
- determine how well the model predicts outcomes
- improve the simplicity and power of the model
- test if the model is consistent with other scientific theories (check the validity of the model).

How well does the model explain its subject?

If a model behaves the way scientists expect it to, they can have confidence that the model correctly explains the subject or phenomenon. For example, consider a simple model of the water cycle you may have used in primary school (Figure 2.10.2a). The model behaves as you predict it would, with water changing from liquid to a gas (and back again), and no water leaving the system. The model therefore correctly explains some of the characteristics of Earth's water cycle (Figure 2.10.2b).



▲ **FIGURE 2.10.2** (a) A model of the water cycle used in an investigation accurately explains some of the processes of Earth's water cycle. (b) A more detailed model of Earth's water cycle.

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denayunebgt/Shutterstock.com

In some areas of study, scientists test models using observations rather than experiments. If observations from a range of independent studies support a model, it builds confidence in the model. In Chapter 17, you will learn about the plate tectonics model, which is supported by a range of evidence.

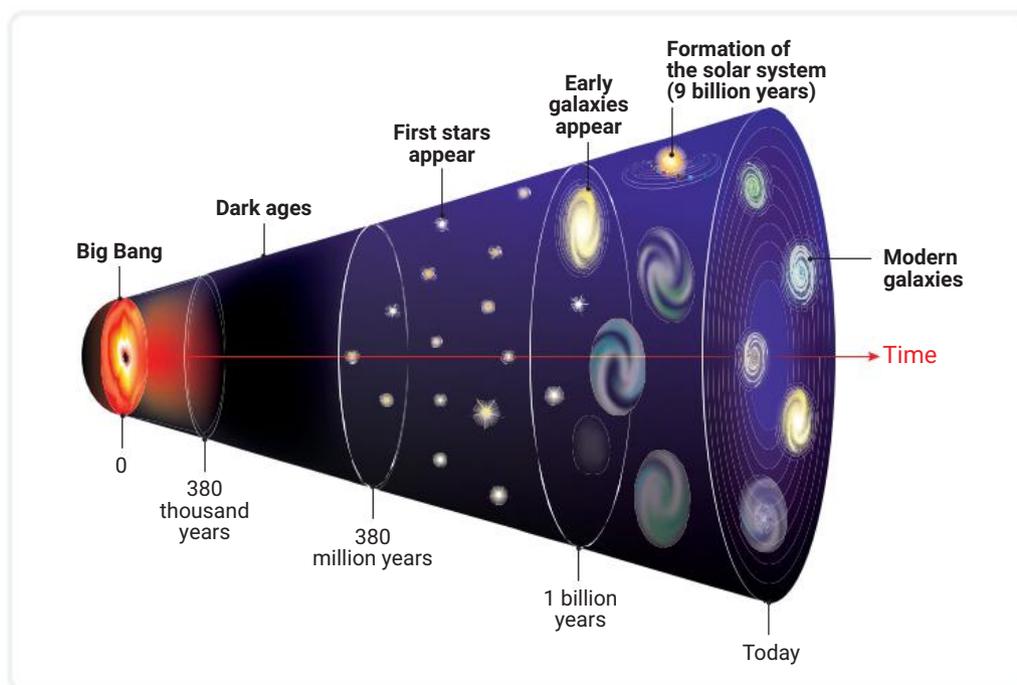
How well does a model predict phenomena?

The predictions that come from models can be investigated. If evidence is found that the predictions are occurring, it strengthens the model.

For example, the scientific theory for the origin of our universe is called the Big Bang theory. Georges Lemaître proposed the theory in 1927, based on the scientific evidence that all the galaxies in space seemed to be moving away from each other (Figure 2.10.3). The Big Bang theory states that the universe expanded suddenly from a small region. Two of its predictions were:

- the universe should mainly contain simple elements such as hydrogen and helium
- there should be energy present from when the universe began, in the form of microwaves.

Years of research and collecting of scientific data support both of these predictions made by the Big Bang theory.

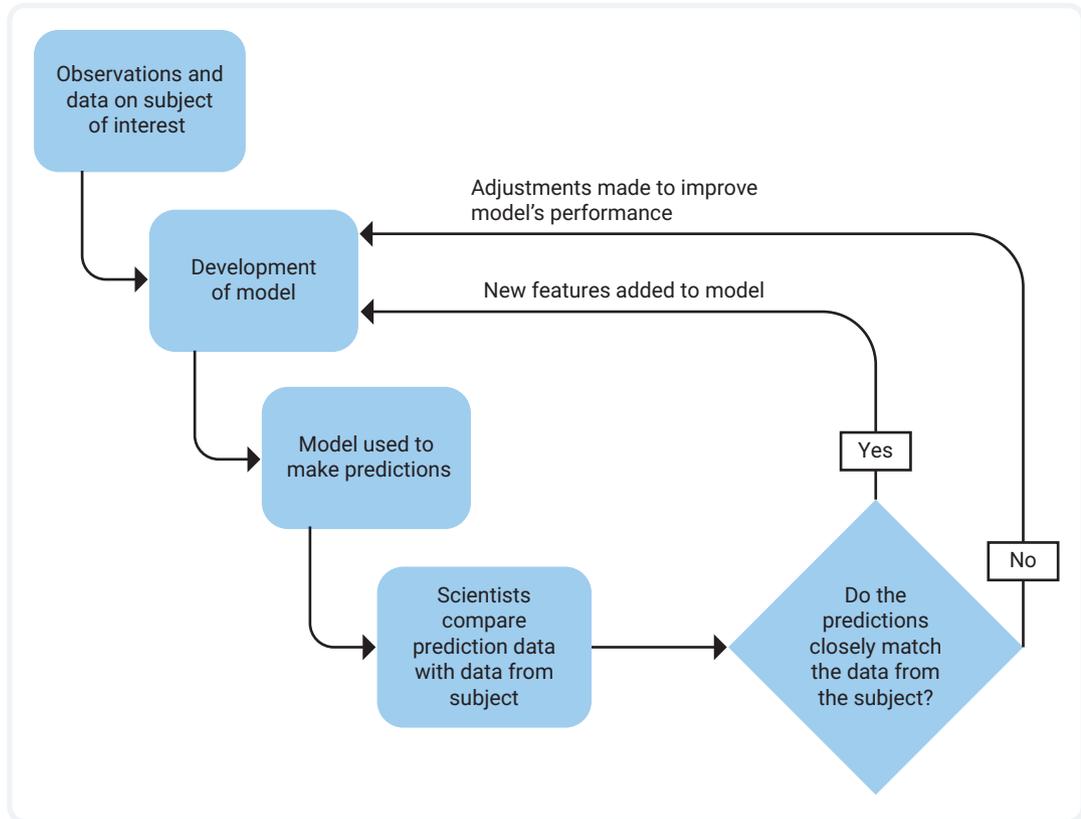


▲ FIGURE 2.10.3 The Big Bang theory explains the origin and evolution of the universe.

Steps in analysing models

If multiple studies by independent researchers generate supporting evidence, scientists have higher confidence in a model. When scientists find non-supporting evidence, they may not completely reject the model. Remember, models are often a simplification of what they represent.

Some models lack details because some things are difficult to observe or measure. Instead, scientists may make modifications to the model to improve its performance. This is what happens with climate models. Using data from the past, climate models make predictions about what the climate should be like. By comparing the predictions with real-life observations, scientists can assess the model and modify it to improve its performance (Figure 2.10.4).



▲ FIGURE 2.10.4 A flow chart of the main steps to analyse a model

2.10 LEARNING CHECK

- 1 **List** the properties of a good scientific model.
- 2 **Describe** two accurate predictions that strengthened the Big Bang model of the universe.
- 3 Why do models not always make accurate predictions?
- 4 **Describe** what it means to refer to a model as 'simple'.
- 5 Browse this textbook and find two examples of models. For each model:
 - a **Describe** what it explains.
 - b **Outline** something the model predicts.
 - c **Identify** another scientific idea that is related to the model.
 - d **Explain** why the model is a good one, or why it is a poor one.

2.11 Data in meteorology

BY THE END OF
THIS MODULE, YOU
WILL BE ABLE TO:

- ✓ identify models as a useful scientific problem-solving strategy
- ✓ analyse data and information.

Each day, Australians use weather apps on their mobile phones to see what the weather is likely to be. Our weather predictions mainly come from the Bureau of Meteorology. On some days, the forecasts match the weather but on other days, the forecasts and the actual weather we experience don't seem to match! Why is this so, and where does the data for the forecasts come from?

Collecting data

Meteorologists make data observations using a wide range of tools. Weather stations on land collect data about temperature, humidity and wind behaviour. Portable weather stations on ships, aircraft, balloons and ocean buoys (Figure 2.11.1) also provide the Bureau of Meteorology with data. Radar can track the movement of storms (Figure 2.11.2). Battery-powered devices called **radiosondes** in balloons measure altitude, pressure, wind and temperature. Satellites gather information about weather from space. Scientists also regularly collect data on sea surface temperatures, and river flow and depth measurements.

meteorologist

a scientist who studies the atmosphere, weather and climate

radiosondes

devices carried by balloons that measure altitude, pressure, wind and temperature in the atmosphere

Suzanne Long/Alamy Stock Photo



▲ FIGURE 2.11.1 An ocean buoy is one source of data about weather and climate.

Analysing and communicating data

Some weather data is sent to the Bureau of Meteorology every minute, but other data is reported every half hour, hour, once a day or once a month. Automatic weather stations send data frequently because it is important for forecasting weather changes and creating information and warnings for the public.

The raw data is fed into computer weather models. The main one used by the Bureau of Meteorology is called ACCESS (Australian Climate Community Earth Systems Simulator).



▲ FIGURE 2.11.2 Collected data is used by models to make the weather predictions we use.

Radar maps for Wollongong, Bureau of Meteorology

Researchers receive forecast data from models such as ACCESS four times a day, comparing the data with that from other weather models to see how consistent the information is. Meteorologists then use the model predictions, and their knowledge, to create weather forecasts.

The Bureau of Meteorology issues seven-day forecasts for locations across Australia. The models scientists use to generate forecasts improve with time, but the atmosphere is complex, and seven days is currently the limit for reliable predictions. During emergencies, the Bureau will issue warnings using weather models to predict the path of destructive winds, storms and hail.

Interpreting forecast data

To make good use of weather forecasts, we need to interpret the data correctly. A forecast summary contains information about winds, temperatures and rainfall (Figure 2.11.3).



▲ FIGURE 2.11.3 An example of a Bureau of Meteorology forecast

The ‘chance of any rain’ forecast tells us how likely it is to have more than 0.2 mm of rain during the day. In this example, there is a 70% chance of receiving more than 0.2 mm of rain at the location. When meteorologists forecast measurable rain, the possible rainfall gives a range. There is a 75% chance of receiving the lower amount listed or more and a 25% chance of receiving the higher amount or more. In the example, the location has a 75% chance of receiving 0 mm or more, and a 25% chance of receiving 15 mm or more. The text summary provides additional information about the nature of the rain: showers, rain or drizzle. The symbol on the left-hand side in Figure 2.11.3 is for showers.

2.11 LEARNING CHECK

- 1 Who collects and interprets weather data for Australia?
- 2 **Describe** three ways that the Bureau of Meteorology collects weather data.
- 3 **List** five aspects of weather that are measured.
- 4 What is the function of the weather model called ACCESS?
- 5 If the chance of rain is 10% and possible rainfall is 1–5 mm, what is the chance of over 5 mm of rain?

2 REVIEW

REMEMBERING

- 1 Name** the term used to describe data created by someone's online activities.
- 2 Describe** two pieces of quantitative data you could collect about a plant like the one in the figure below.

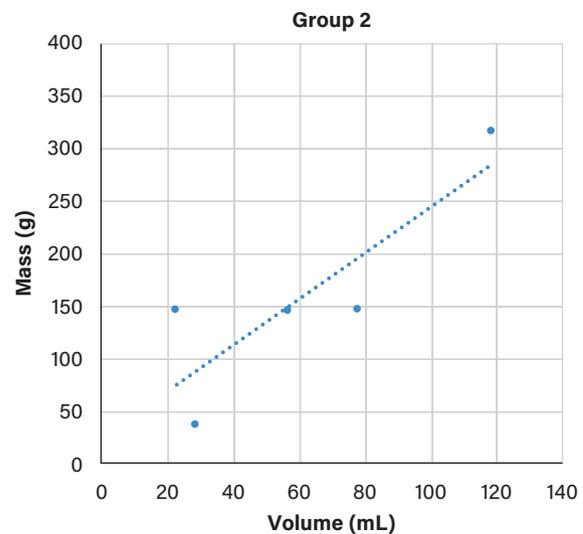
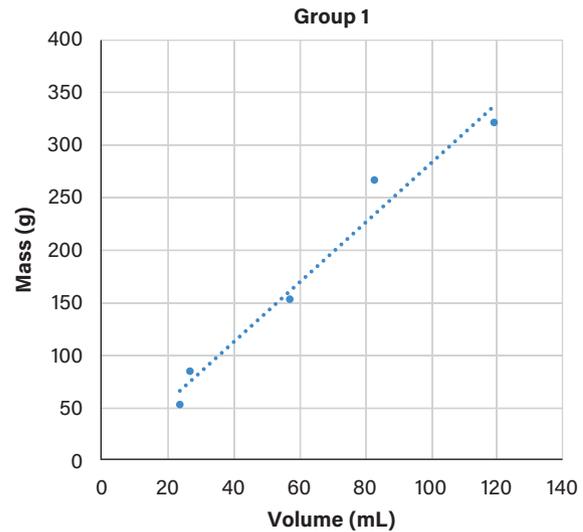
Pekka Nikonen/Shutterstock.com



- 3 Define** the following terms:
 - a** scientific model.
 - b** secondary data.
 - c** pseudoscience.
 - d** trend.
- 4 List** three reasons scientists use models.
- 5 Describe** how scientists use raw weather data to generate weather forecasts and warnings.

UNDERSTANDING

- The following graphs show the data gathered by two groups during an experiment to measure the density (mass per unit volume) of a material.
 - a Identify** the group with the strongest correlation between mass and volume.
 - b Explain** why Group 2's line of best fit shows a different slope from Group 1's line of best fit.



- People often share personal information on social media with friends. **Explain** why sharing personal details online can generate an unwanted digital footprint.
- Explain** why phrenology is classified as a pseudoscience.
- List** three differences between quantitative and qualitative data.

10 Identify whether the following sentences are true or false. If the sentence is false, rewrite the sentence to make it true.

- a** Quantitative data is data which does not use numbers.
- b** Scientific models always generate correct predictions.
- c** Astrology is a scientific discipline.
- d** Ensuring reliability of secondary data involves checking the data is up to date.
- e** A secondary source is a document that describes research you have carried out yourself.
- f** Scientific diagrams are a way to summarise data.

11 Explain why it is important to plan how you will collect data in an investigation.

12 Graphing data is an important step in data analysis.

- a State** an example of something that a graph will show better than statistics alone.
- b Explain** how an outlier might change the line of best fit for a dataset.

APPLYING

13 Explain how you can improve a scientific model by testing its predictions.

14 Create a table to compare qualitative and quantitative data. Include examples.

15 The table below shows two datasets.

Dataset A (g)	23	26	26	28	29	30
Dataset B (amps)	11.5	16.2	12.7	11.9	14.2	12.5

a Identify the maximum value in Dataset A.

b Reorder Dataset B from smallest to largest value and **calculate** the median.

c Calculate the mean of each dataset.

d Compare the ranges for the two datasets.

16 Paula conducted an experiment and measured how quickly an acid dissolved a substance. She collected the following data.

Time (minutes)	Mass of substance remaining (g)
0	9.9
1	9.9
2	9.6
3	9.6
4	9.5
5	9.3
6	9.3

a Graph the data and draw a line of best fit for the graph.

b Predict, using the line of best fit, the mass of substance remaining after 1.5 minutes.

c Explain why the line of best fit is a model of the data.

17 Justify the use of secondary sources in scientific investigations.

18 Construct a table to compare the cleaning, exploration and modelling of data. Use examples of each stage in your table.

EVALUATING

- 19** To model how ice in a glacier flows, students were given a choice of playdough and fine sand to flow down a sloping surface. How would you **judge** which material made the better scientific model?
- 20** Models generate predictions that can be tested.
- a Explain** how the failure of a model to correctly predict something can lead to the model becoming stronger.
 - b** Why is it true to say that most models are wrong?
- 21** The table below contains rainfall data for a country town in New South Wales.
- a Plot** the median rainfall for the 12 months. (Hint: What sort of graph is appropriate for the two variable types?)
 - b Explain** why the median values are less than the averages for each month.
 - c** What additional information do you need to judge the reliability of this data?

Rainfall (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	69.8	57.0	58.2	51.4	52.5	59.6	59.6	61.9	54.7	58.4	60.6	64.1
Median	60.0	41.4	46.0	38.7	49.4	50.9	54.0	57.3	47.4	50.8	48.5	62.3
Highest daily	110.4	116.0	196.6	102.4	69.9	71.6	62.0	65.0	58.7	66.5	95.0	81.5

- 22** A graph describing a dataset has a line of best fit applied to the data.

- a Explain** the effect of an outlier on the line of best fit.
- b** Why should you keep the outlier as part of the dataset?
- c** How can graphing data as you collect it help you to overcome the problem of including outliers that are due to errors in measurement reading or recording?

CREATING

- 23 Create** a table of data variables you might measure or describe in an investigation of the plants in a garden and the factors affecting their growth. Divide the data in the table into qualitative and quantitative types.

SCIENCE IN DEPTH STUDY

#2

1 Connect what you've learned

In this chapter, you've learned how to visualise and describe trends in data, and about secondary sources of data and the use of models. Create a flow chart starting with creating a model and ending with communicating learning. Ensure that you include data gathering, visualisation and modelling data in the flow chart.

2 Check your thinking

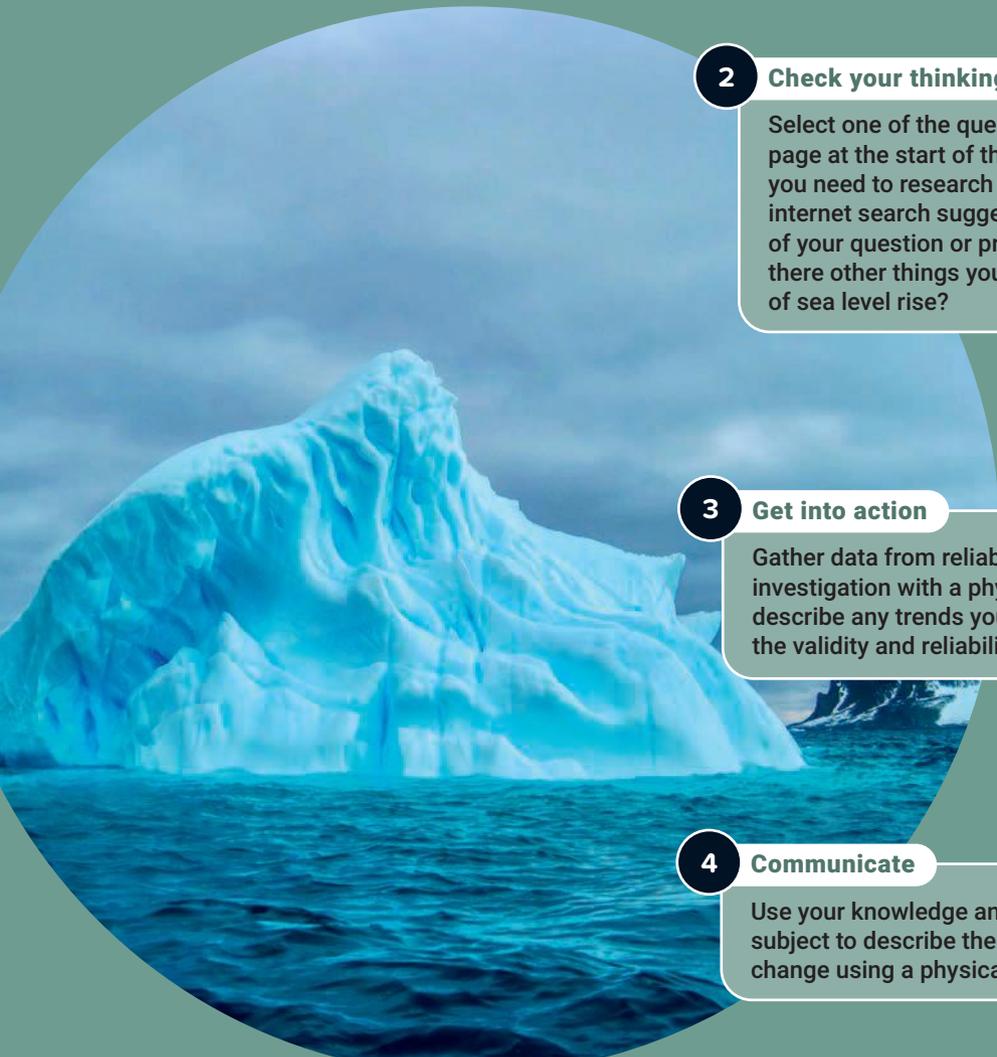
Select one of the questions from the Science in Depth #2 page at the start of the chapter (p. 59). What ideas will you need to research using secondary sources? Will an internet search suggest a way of modelling the subject of your question or provide data on the change? Are there other things you need to know to model an aspect of sea level rise?

3 Get into action

Gather data from reliable scientific sources, or from an investigation with a physical model. Graph your data and describe any trends you identify. Make a judgement about the validity and reliability of your investigation.

4 Communicate

Use your knowledge and understanding of your research subject to describe the effects of your subject on climate change using a physical model or other suitable model.



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OBSERVING THE UNIVERSE

SYLLABUS OUTCOMES

A STUDENT:

- ▶ explains how observations are used by scientists to increase knowledge and understanding of the Universe SC4-OTU-01
- ▶ uses scientific tools and instruments for observations SC4-WS-01
- ▶ follows a planned procedure to undertake safe and valid investigations SC4-WS-04

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CHAPTERS RELATED TO THIS FOCUS AREA ARE:

- ▶ **CHAPTER 3** – NATURE AND PRACTICE OF SCIENCE
- ▶ **CHAPTER 4** – SPACE SCIENCE



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3

Nature and practice of science

3.1 What is science? p. 106

Science uses knowledge to help us understand the world.

3.2 Branches of science p. 108

There are many different branches of science, including biology, chemistry, physics and geology.

3.3 Scientists working together p. 110

Scientists work in collaboration with each other, sharing knowledge and expertise, to enrich the advancement of science.

3.4 Scientific theories and laws p. 112

Scientific theories and laws are created by following scientific processes. Theories are explanations of phenomena while laws are descriptions of what happens in phenomena.

3.5 Safety in practice p. 114

Safety is an essential part of conducting investigations. There are specific rules and procedures when working in the science laboratory.

3.6 Using a Bunsen burner p. 117

The Bunsen burner is a common piece of equipment in science and its safe use means following a specific set of safety rules.

3.7 WORKING SCIENTIFICALLY: Bunsen burner safety p. 120

Following the safety rules to use the Bunsen burner

3.8 Measuring in science p. 121

Using the appropriate equipment allows us to make accurate measurements to collect data.

3.9 WORKING SCIENTIFICALLY: Practise using laboratory equipment p. 125

Collecting accurate measurements when ice is added to water

3.10 SCIENCE IN CONTEXT: From burrs to Velcro p. 127

Observations and questions can lead to scientific advances.



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Forensic investigations of crime scenes are examples of interdisciplinary scientific investigations. To solve a crime, scientists from many branches of science need to work together. Depending on the crime, you may need scientists such as experts on ballistics, microbiologists, medical practitioners, toxicologists, physicists, engineers, pathologists and biometricians. Forensic scientists work collaboratively (as a team) to analyse evidence and reach conclusions. They will all follow the processes of working scientifically to solve the case.

- ▶ What is the expertise of each type of scientist listed above?
- ▶ How would you collect evidence from a crime scene if the only evidence is fingerprints?
- ▶ What other experts would you need to consult to analyse a crime scene?

▲ FIGURE 3.0.1 Crime scenes are analysed by teams of scientists.

#3 DIVE INTO SCIENCE!

At the end of this chapter, you can complete Science in Depth Study #3. You can use the information you learn in this chapter to complete the project.

Assessments

- Prior knowledge quiz
- Chapter review questions
- End-of-chapter test
- Depth study: Science report

Videos

- Science skills in a minute: Measuring liquids (3.8); Lab equipment (3.9)
- Video activities: Why science matters (3.1); Australia's award-winning Aboriginal and Torres Strait Islander scientists (3.2); Theories, hypotheses and laws (3.4)

Science skills resources

- Science skills in practice: Accurately measuring liquids (3.8); Using lab equipment (3.9)

Interactive resources

- Drag and drop: Branches of science (3.2)
- Label: A Bunsen burner (3.6)
- Quiz: Measuring in science (3.8)

3.1 What is science?

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define science and explain the role of science in our lives
- ✓ give examples of science in your everyday life.

GET THINKING

With your classmates, make a list of things that have been invented or discovered since you started primary school. Discuss what was needed for those inventions or discoveries to be possible.

science

the study of the natural and physical world by asking questions, making predictions, gathering evidence, solving problems and revising knowledge

theory

an explanation of why a phenomenon happens

law

a description of what happens in a phenomenon

scientist

a person who uses research to gain knowledge and understanding of any area of science

stereotype

a set idea about something or someone

Science is a system of studying the world

Science is a system of studying the world to solve problems. More specifically, it is a system of processes that uses observation and experimentation to gain knowledge and understanding of the world.

In Chapter 1, you learned about the working scientifically processes. These processes are an important part of the nature and practice of science. The nature and practice of science are based on the following concepts:

- scientific knowledge is subject to change over time when new ideas, models, **theories** and **laws** are presented
- science is based on observations from the world around us
- science involves creativity, collaboration and inferences
- science aims to solve problems and better understand the world.



▲ **FIGURE 3.11** Scientists work in a range of different places: (a) under water, (b) in a zoo, (c) in a mine, (d) in a laboratory.

Scientists study many different things and use a wide variety of methods. When we think of scientists, we often picture a **stereotype** of what scientists look like and where they work – old male professors in white lab coats, working in a laboratory full of glass beakers, jars of chemicals and microscopes. However, scientists of all genders can come from a range of backgrounds and ages. Scientists also work in many different locations, and they wear clothes and use equipment that suits a particular purpose. For example, some scientists work in factories, on farms or in hospitals. Others work in or near water, around rocks or ice, at a zoo or even in space. Some scientists spend their working life in an office, using a computer to analyse data or to create models.

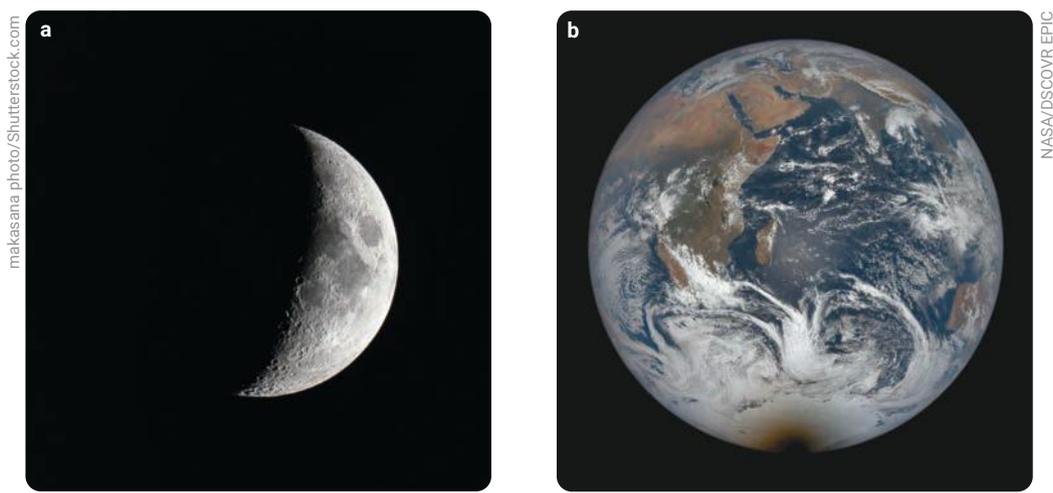


Video activity
Why science matters

philosopher
a person who studies or writes about the truths related to knowledge

Science is an ongoing study, with scientists always learning. Sometimes, discoveries are about new things, but sometimes they show us that our previous understanding wasn't quite right. In these cases, scientists adjust and update models, theories and laws to reflect the new information. This isn't something new, though. For example, people used to think that Earth was flat because that is how it appeared to them. However, more than 2500 years ago, early scientists noticed that some things didn't make sense if Earth was flat. For example, why didn't travellers fall off the end of Earth? Then Socrates, a Greek **philosopher**, saw that the shadow during a lunar eclipse was curved (Figure 3.1.2) and he proposed that this was because Earth was round. At first, this proposal faced strong opposition from people who believed Earth was flat. However, over time, more scientists made observations and measurements that showed Earth is round, until it became widely accepted.

More recently, scientists have applied new knowledge to develop vaccines for the virus that causes COVID-19. Traditional vaccines had not been effective against the virus. Scientists worked together internationally to share information. They created and tested new types of vaccines that have helped millions of people to fight the COVID-19 pandemic.



▲ FIGURE 3.1.2 (a) The curved shadow from Earth during a lunar eclipse was evidence supporting that (b) Earth is round.

3.1 LEARNING CHECK

1 Define:

- a science.
- b scientist.

2 When you were young, you learned to write the letters of the alphabet. Then you learned to combine letters to make words, before using words to write sentences. **Explain** how this is similar to scientists updating their understanding as they gain new knowledge.

3 Do you think scientists will ever stop making new discoveries? **Explain** your answer.

4 Use the internet to explore some recent advances made by science. The weblinks on this page are good starting points. Focus on one idea and **create** an advertisement in the form of a poster to 'sell' the idea to the rest of the class.



- Weblinks
- Science daily
- New Scientist
- Scientific American
- ABC Science
- CSIRO

3.2 Branches of science

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe different branches of science
- ✓ define astronomy, biology, chemistry, environmental science, geology and physics
- ✓ explain how scientists work.



Video activity

Australia's award-winning Aboriginal and Torres Strait Islander scientists

Interactive resource

Drag and drop: Branches of science

GET THINKING

Scientists everywhere use common terminologies when describing the different areas of science so that everyone has the same understanding. Therefore, an important part of learning science is learning the meaning of key terms. One way to learn the definitions of terms is to use flashcards.

- 1 Choose how you will make your flashcards; for example, on paper or card, or by using an app.
- 2 Make a set of flashcards for any branches of science that you already know.
- 3 As you work through this module, add to your flashcards until you have a set that includes all the branches of science that your teacher wants you to learn.
- 4 Use your flashcards to practise remembering the definitions for the branches of science.

Scientists at work

Scientists work in all areas of the world around us. There are so many different things to study that the different areas, or branches, have specific names. Some key branches of science are:

- **biology** – the study of living things
- **chemistry** – the study of the composition and properties of matter
- **geology** – the study of the liquid and solid parts of Earth
- **physics** – the study of matter, energy and the interaction between them
- **astronomy** – the study of objects beyond Earth, including stars, other planets and galaxies.

Working across different branches of science

Scientists often work in areas that involve more than one branch of science. This is why science is often described as being **interdisciplinary**. Sometimes these areas are given their own name, which reflects the branches of science that they use. For example, biochemistry is the study of the chemicals and their processes in living organisms.

Other examples are:

- **environmental science** – the study of the conditions of the environment and their effects on all organisms
- geochemistry – the study of the chemical composition of Earth
- astrophysics – the study of how the stars, planets and other celestial objects work
- marine biology – the study of organisms in saltwater environments.

biology

the study of living things

chemistry

the study of the composition and properties of matter

geology

the study of the liquid and solid parts of Earth

physics

the study of matter, energy and the interaction between them

astronomy

the study of objects beyond Earth, including stars, other planets and galaxies

interdisciplinary

involving knowledge from different branches of science

environmental science

the study of the conditions of the environment and their effects on all organisms



▲ FIGURE 3.2.1 (a) Biology, (b) chemistry and (c) physics are branches of science.

Scientists are named according to the area of science that they study, so that it is clear what they do. For example, a chemist studies chemistry and a biologist studies biology. Some scientists study a very specific area of science and so their name reflects this. For example, a neurologist studies the nervous system and a vulcanologist studies volcanoes.

There are also **transdisciplinary scientists**, who are trained in multiple branches of science.

transdisciplinary scientist

a scientist who is trained in knowledge from different branches of science

3.2 LEARNING CHECK

- 1 What branch of science is the study of living things?
- 2 What branch of science will you be studying when you learn about energy and matter?
- 3 What would a scientist who studies astronomy be called?
- 4 Over the last few decades, scientists have worked together to understand climate change. What areas of science have contributed to our current knowledge? For each area, **suggest** what scientists would have learned or contributed.
- 5 Scientists work in many different fields of science. The following list represents just a few of these scientists.

- | | | |
|-------------------|-----------------|--------------------|
| • Microbiologist | • Haematologist | • Archaeologist |
| • Ecologist | • Lepidopterist | • Zoologist |
| • Anthropologist | • Oceanologist | • Botanist |
| • Entomologist | • Agronomist | • Marine biologist |
| • Palaeontologist | • Apiologist | • Pharmacologist |
| • Geneticist | | |

- a Find out what each of the scientists do. **Record** your answers in a table.
- b Did you notice that most of the names in the list end in '-ologist'? Find out what this means. Find two other '-ologist' scientists to add to your list.
- c **Choose** one of the types of scientists from your list to conduct further research.
 - i What does this type of scientist study?
 - ii If you became this type of scientist, where might you work and what might you do in a typical day?
 - iii Who is a famous scientist working in this field? What did they discover?
 - iv **Present** your findings in an infographic.

DATA SCIENCE



Learn about data scientists in **Modules 2.4 and 2.5.**

3.3 Scientists working together

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define collaborative work
- ✓ describe the importance of working in collaboration with others.



Video activity
Collaborating to end plastic waste

GET THINKING

Imagine you and your classmates are stuck on a deserted island and your mobile phone isn't working. You need to invent a device to communicate with a passing ship so they can rescue you. How are you going to do it? What prior knowledge do you have about communication devices that could help you? What materials would you need? Share your ideas with your classmates and discuss how you could collaborate to invent the device.

Scientists working together

Throughout the history of science, many scientists have worked independently, making important discoveries alone. Today, it is rare for scientists to work in isolation.

Collaborative work between scientists from different disciplines and from different parts of the world enriches science. Successful collaborations result in faster discoveries and developments to the benefit of society.

For collaborative work to be successful, scientists usually need to:

- agree on the aims of their research
- be respectful when disagreeing with each other
- share resources
- communicate with each other clearly and often
- share their findings with the scientific community.

Examples of great scientific collaboration

The development of artificial limbs started a long time ago, as shown by the discovery of an artificial toe made of leather and timber on a mummy in Egypt. Since then, there have been many improvements to artificial limbs as new materials have become available and ideas have developed. Today, bioengineers and biophysicists are developing artificial limbs that can be controlled by electrical impulses from the brain. These advances in technology are possible because scientists have built on previous knowledge and technology to create new ideas, resulting in better artificial limbs.



▲ **FIGURE 3.3.1** The development of artificial legs from wooden stumps to those controlled by the brain was due to continued building of ideas.

collaborative work
work carried out by many people by sharing ideas and knowledge

Another example that illustrates how scientists work collaboratively is research into how to reduce plastic waste worldwide. Australian scientists from CSIRO, in collaboration with the Vietnamese Government, created the Plastics Innovation Hub Vietnam (Hub Vietnam) with the aim of reducing plastic waste in the ocean. In this initiative, scientists, governments, businesses and investors work together to develop new recycling systems and plastic alternatives.



Rich Carey/Shutterstock.com

▲ FIGURE 3.3.2 Plastic waste in the ocean is a huge environmental problem. Complex issues like this need teams of scientists to work together collaboratively to find solutions.

3.3 LEARNING CHECK

- 1 **Define** collaboration in science.
- 2 **Explain** the main features of good collaboration between scientists.
- 3 **State** the importance of working in a collaborative environment in scientific research.
- 4 You are part of a research team working on developing a flexible material to use as solar panels in cars. **Discuss** what previous knowledge your team will need to build upon to develop this type of technology.
- 5 A group of scientists in an agricultural research facility took the results of another team and published them as their own. **Discuss** the consequences of using data from other scientific teams without consulting or collaborating with them.

3.4 Scientific theories and laws

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define theory and laws
- ✓ state how theories and laws are developed.



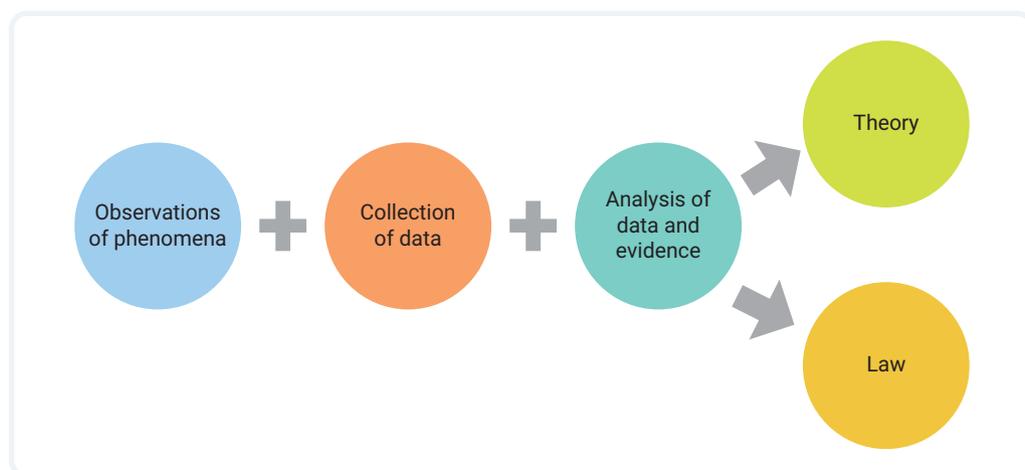
Video activity
Theories, hypotheses
and laws

GET THINKING

In Australia, there are many laws that people must follow. In groups of three, list the different types of laws that you know about. What are the similarities and differences between the laws? Do these laws apply to different rules and procedures? In your group, discuss how new laws are created.

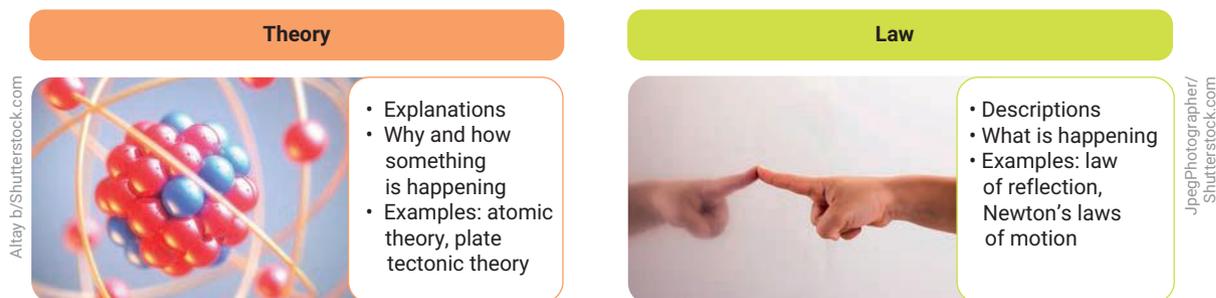
Defining theory and law

Scientific theories and laws are conclusions. They are both based on the collection and analysis of experimental data and observations carried out over a long time (Figure 3.4.1).



▲ FIGURE 3.4.1 Scientific processes lead to the development of a theory or a law.

Although they are developed the same way, scientific theories and laws have a fundamental difference: theories explain *why* a phenomenon is happening and laws describe *what* is happening (Figure 3.4.2). For example, the theory of plate tectonics explains why the continents move. In contrast, the Newton's laws of motion describe how objects move and behave under certain circumstances. Scientists use both scientific theories and laws to make predictions.



▲ FIGURE 3.4.2 Differences between a scientific theory and a scientific law

The beginning of theories and laws in science

Over the centuries, many philosophers have tried to explain the world around them. Ancient philosophers called these observations and explanations theorems or principles, rather than laws or theories.

The first written observations about scientific phenomena date from Babylonian clay tablets, around 3600–3900 years ago, where someone tried to explain the movement of the planets. Many of these early explanations were based on **intuition** and simple observations rather than collected data. Some of the first correct laws in the ancient world were the ones developed over 2200 years ago by Archimedes, a mathematician and inventor from ancient Greece. He published observations about **buoyancy** (Archimedes' principle; Figure 3.4.3) and levers and screws (Archimedes' screw) among many other theories and inventions.

intuition

to know something without needing to think about it or study it

buoyancy

the upward force exerted by a liquid on an object



▲ Figure 3.4.3 One of Archimedes many discoveries was supposedly made in the bath, when he realised there was a link between an object's buoyancy and its displacement of water.

3.4 LEARNING CHECK

- 1 **Define** the science terms theory and law.
- 2 **Describe** how ancient philosophers tried to explain phenomena.
- 3 **Explain** how theories and laws are developed.
- 4 **Imagine** you could go back in time and interview Archimedes. **Create** three questions that you would ask him about his theories.
- 5 Do some research and then **outline** a short procedure to use tools to observe evidence from one of the laws below:
 - law of reflection
 - Newton's first law – inertia
 - law of conservation of mass.

3.5 Safety in practice

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ identify safety risks in the laboratory by conducting a risk assessment
- ✓ apply safety procedures when conducting investigations.



Video activity
Why we do risk assessments

GET THINKING

Fire fighters have to keep themselves safe in dangerous situations. Think about what conditions are like during a bushfire. List all the safety rules you think fire fighters would have to follow. How does this compare with the safety rules in the science laboratory in your classroom? Create a Venn diagram to compare and contrast both situations. You can refer to the list of safety rules in Module 1.7.

risk assessment

an assessment of potential hazards and how to minimise them

hazard

something that has the potential to harm

Assessing safety in the laboratory

To stay safe in the science laboratory, you need to know exactly when to follow specific safety procedures. This is why it is important to conduct a **risk assessment** to identify any **hazards** before you conduct an experiment. A risk assessment considers the safety procedures you need to follow before, during and after the experiment (Table 3.5.1).

▼ TABLE 3.5.1 Management of safety risks before, during and after an investigation

Risk assessments for:	Before the investigation	During the investigation	After the investigation
Use of chemicals	Check the safety label on the chemical container.	Wear goggles, lab coat and gloves when using the chemical.	Tell the teacher if you spill a chemical. Close the chemical bottle/ container immediately.
Use of glassware	Place the glassware away from the edge of the bench.	Handle glassware with care. Wear goggles, gloves and lab coat.	Place the equipment in the container to be washed. Notify the teacher if any breakages happen.
Use of hot equipment	Check that the equipment can be heated safely.	Handle hot equipment with care. Use tongs to move hot equipment. Wear goggles, gloves and lab coat.	Wait until the equipment has cooled before putting it away.

likelihood

the chance something will happen

consequence

the result of a decision or action

Risk assessment matrix

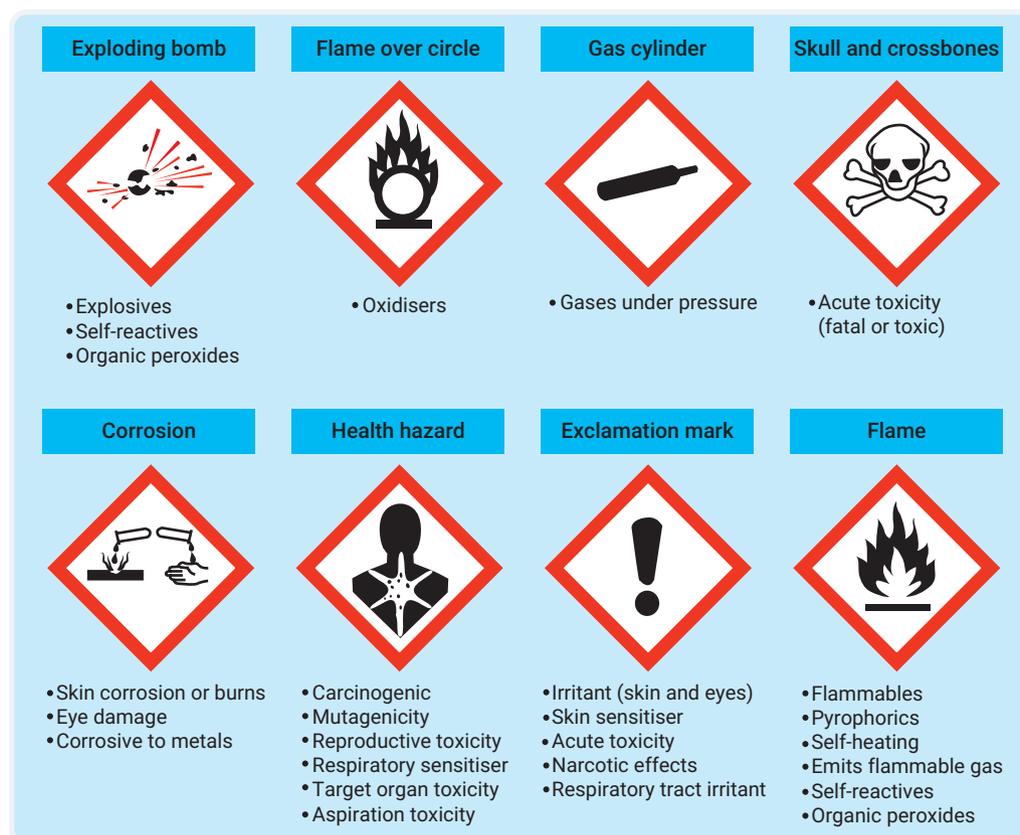
Scientists around the world follow a risk assessment matrix to assess any potential hazards in their laboratory or investigations (Table 3.5.2). To determine a risk, the matrix combines the **likelihood** of something occurring with the severity of any potential **consequences**. For example, if you are going to use the Bunsen burner in the science laboratory, you can say that it is possible (likelihood) that you will get a slight burn (consequence). Using this information and the matrix below, you can classify the overall risk of using a Bunsen burner as minor to moderate.

▼ TABLE 3.5.2 An example of a risk assessment matrix

Risk	Likelihood				
	Rare	Unlikely	Possible	Likely	Almost certain
Severe: For example, potentially fatal or causing an injury or illness with permanent disability	MEDIUM	MEDIUM	HIGH	EXTREME	EXTREME
Major: For example, causing an injury that could cause lost time, but not permanent disability	LOW	MEDIUM	MEDIUM	HIGH	EXTREME
Moderate: For example, causing an injury or illness requiring moderate medical treatment but not lost time	LOW	LOW	MEDIUM	MEDIUM	HIGH
Minor: For example, causing an injury potentially requiring application of first aid	LOW	LOW	LOW	MEDIUM	MEDIUM
Minimal: For example, a hazard or near-miss that requires reporting and follow-up action	LOW	LOW	LOW	LOW	LOW

Labelling of chemicals

We use many different chemicals in the science laboratory. To help manage the potential hazards from chemicals, science laboratories, including those in schools, must use a set of labels known as the Global Harmonised System (GHS). These labels indicate different types of hazards using pictograms (Figure 3.5.1). The labels go on all chemical bottles and containers.



▲ FIGURE 3.5.1 Pictograms from the Global Harmonised System used to label chemicals in school and other laboratories

safety data sheet (SDS)

a document that provides information about the hazards and risks associated with a substance or material

agar plate

a transparent dish with lid containing a jelly-like substance called agar, used for growing bacteria or fungus in the laboratory

autoclave

a machine that uses steam at very high pressure to kill microorganisms on instruments and equipment

In schools, coloured dots are placed on bottles and containers to indicate how the chemicals can be used. For example, a green dot may indicate that all students can use that chemical and a red dot may indicate that only teachers can use a chemical to do demonstrations.

Disposal of materials

At the end of an investigation, chemicals must be disposed of correctly. Some chemicals can be disposed of down the laboratory sink with lots of water. Other chemicals need to be securely sealed and stored and then later collected for a special type of disposal. Scientists follow the information on a chemical's **safety data sheet (SDS)**, which explains how to handle and dispose of the chemical. In the school laboratory, your teacher or lab technician will tell you how to dispose of different chemicals.

In investigations that use cultures of live bacteria or fungi, you should never open an **agar plate** and you should wear gloves when handling one. Agar plates must be heated in an **autoclave** to kill the bacteria or fungi before disposal.



Pornsuda Thaisa/Shutterstock.com

▲ FIGURE 3.5.2 Always wear gloves when manipulating live cultures on agar plates.

3.5 LEARNING CHECK

- 1 **Describe** how scientific processes are linked to safety in the laboratory.
- 2 Glass equipment may break during an experiment. **Describe**, using the risk matrix, the level of risk that broken glass presents in the laboratory.
- 3 Observe the following labels on chemical bottles. **Explain** which ones you, as a Year 7 or 8 student, can use in your investigations. **Discuss** what risk is indicated by the label 'flammable' on the right-hand bottle.



3.6 Using a Bunsen burner

3.6

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ state the names and functions of the parts of a Bunsen burner
- ✓ describe how to safely light a Bunsen burner
- ✓ explain the difference between a blue flame and an orange flame, and when to use each.

GET THINKING

You can maximise your learning by being prepared. To prepare for learning about the Bunsen burner, take a photo or find a diagram of a Bunsen burner. As you learn about the parts of the Bunsen burner, label them with the name and function. Use a different colour for each part – this will help you remember the information.



Interactive resource
Label: A Bunsen burner

Parts of the Bunsen burner

A Bunsen burner is very similar to a gas barbecue: gas burns to produce heat and light. In science, we use the heat from the Bunsen burner to heat objects and chemicals.

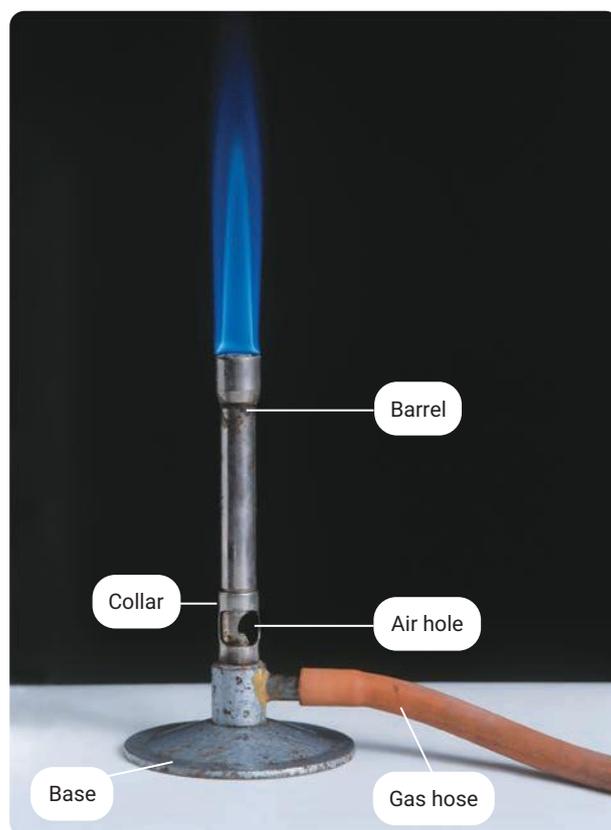
The bottom of the Bunsen burner, called the **base**, is flat to ensure that the Bunsen burner is stable on the bench. The gas enters the Bunsen burner through the **gas hose**, which is connected to the **gas tap**. Air enters the Bunsen burner through the **air hole** and travels up the **barrel** with the gas. When the burner is lit, the oxygen in the air reacts with the gas, producing a flame at the top of the barrel. The amount of air mixing with the gas is controlled by opening or closing the air hole by turning the **collar**. You can see the parts of a Bunsen burner in Figure 3.6.1.

Types of flames

A Bunsen burner has two types of flames: an orange or **safety flame**, and a **blue flame**. You can see these two types of flame in Figure 3.6.2.

The orange flame is known as the safety flame because it is easy to see. It is a cooler flame because it occurs when the air hole is closed, meaning that there is less oxygen available. This type of flame produces black soot and will dirty the glassware. Therefore, it is not used when heating substances.

The blue flame is produced when the air hole is open. It is a hotter flame than the orange flame because of the extra oxygen available. Because it is cleaner and hotter, a blue flame is used to heat substances. However, the blue flame is difficult to see, so the flame should always be changed back to the orange safety flame when not being used to heat objects.



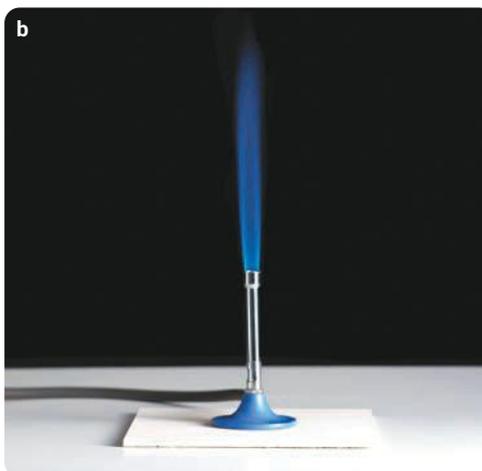
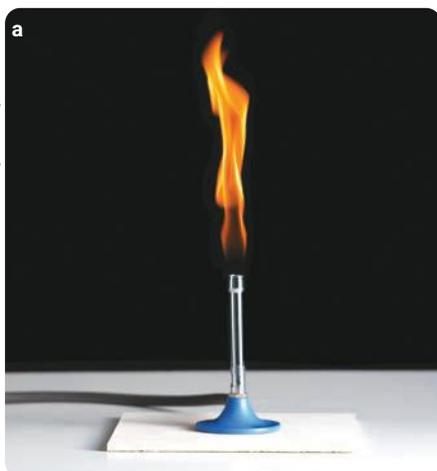
▲ FIGURE 3.6.1 The parts of a Bunsen burner

safety flame

the cooler flame from a Bunsen burner that is easily visible because it is orange; also known as the orange flame

blue flame

the hottest flame from a Bunsen burner



▲ FIGURE 3.6.2 A Bunsen burner with (a) an orange flame (the safety flame) and (b) a blue flame

Lighting a Bunsen burner safely

The following steps tell you how to safely light a Bunsen burner:

- 1 Place the Bunsen burner on a heatproof mat.
- 2 Check that there is no damage to the gas hose.
- 3 Connect the gas hose securely to the gas tap.
- 4 Close the air hole.
- 5 Light the match or gas lighter.
- 6 Hold the match or gas lighter just above and slightly to the side of the top of the barrel.
- 7 Turn the gas tap on. An orange flame should appear from the top of the Bunsen burner.
- 8 When heating objects, turn the collar to open the air hole. This will turn the flame to blue.

Turning off the Bunsen burner

When you have finished using the Bunsen burner, turn the gas tap off. The remaining gas will react and then the flame will go out. This ensures that there isn't any unreacted gas released into the room; this would be dangerous.

Sometimes the flame may get blown out. If this happens, turn the gas tap off immediately to stop gas being released.



▲ FIGURE 3.6.3 (a) The gas tap is turned on when the tap is pointing in the same direction as the outlet. (b) The gas tap is turned off when the tap is pointed away from (90°) the direction of the outlet.

3.6 LEARNING CHECK

3.6

1 **Match** each part of the Bunsen burner with its function.

Barrel

• Allows the Bunsen burner to sit upright

Gas tap

• Carries gas to the Bunsen burner

Base

• Controls how much air mixes with the gas

Air hole

• Carries the gas up the Bunsen burner

Gas tube

• Opens or closes the air hole

Collar

• Controls whether gas is released or not

2 Copy and **complete** the table with information about the two types of flames.

Description	Orange flame	Blue flame
Temperature (very hot or hot)		
Clean or dirty (produces soot)		
Safety flame (yes or no)		
Air hole open or closed		
Amount of oxygen (high or low)		

3 **Explain** why it is important that the gas tap is turned on after the match is lit and held above the barrel, and not before.

4 Under your teacher's supervision, set up a Bunsen burner on a heatproof mat with a tripod stand and gauze mat. Put a piece of wax in a beaker and place the beaker on the gauze mat. Light your Bunsen burner and open the air hole to turn it to a blue flame. Heat the wax until it has all melted. Close the air hole to change the flame to an orange flame and then turn the gas off. Leave the equipment to cool, then follow your teacher's instructions to pack the equipment away. **Describe** the blue flame and explain why it was used when you were heating the wax.

5 Many people use videos to learn how to do new things. **Create** an instructional video about how to light a Bunsen burner. Your teacher may let you take videos or photos showing the steps or you could use drawings instead. Add voice-overs and text for each step so that it is clear. If you do not have access to a video-recording device, create a simple picture book to show the steps.



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THIS SKILL:

- ▶ practising using the Bunsen burner.

Follow these steps to safely light a Bunsen burner:

- 1 Place the Bunsen burner on a heatproof mat.
- 2 Check that there is no damage to the gas hose.
- 3 Connect the gas hose securely to the gas tap.
- 4 Close the air hole.
- 5 Light the match or gas lighter.
- 6 Hold the match or gas lighter just above and slightly to the side of the top of the barrel.
- 7 Turn the gas tap on. An orange flame should appear from the top of the Bunsen burner.
- 8 When heating objects, turn the collar to open the air hole. This will turn the flame to blue.
- 9 When you finish working with the Bunsen burner, open the air hole and turn the gas tap off.
- 10 Leave the Bunsen burner to cool for a couple of minutes before you pack it away.

USING A BUNSEN BURNER

Safety

Flames from Bunsen burner can cause burns or damage equipment. Make sure that all hot equipment cools down before you touch it.

Always turn off the Bunsen burner if you are not working with it or leave it showing the orange safety flame when you are between the steps of an experiment.

Remember to tie back your hair if it's long and wear safety goggles at all times.

AIM

To practise using the Bunsen burner.

MATERIALS AND EQUIPMENT

- | | |
|---|--|
| <input checked="" type="checkbox"/> Bunsen burner | <input checked="" type="checkbox"/> 1 watch glass |
| <input checked="" type="checkbox"/> heatproof mat | <input checked="" type="checkbox"/> 200 mL beaker |
| <input checked="" type="checkbox"/> wooden icy-pole stick | <input checked="" type="checkbox"/> 100 mL distilled water |
| <input checked="" type="checkbox"/> 10 g table salt | |

PROCEDURE

- 1 Set up the Bunsen burner on the heatproof mat.
- 2 Place 100 mL of distilled water in the beaker.
- 3 Soak the icy-pole stick in the distilled water for around two minutes.

- 4 Place a small amount of table salt on the watch glass.
- 5 Remove the icy-pole stick and dip it in the table salt, making sure the tip is well covered.
- 6 Follow the steps to light the Bunsen burner safely.
- 7 Open the air hole to use the blue flame.
- 8 Gently, place the icy-pole stick near the top of the blue flame without burning the wood.
- 9 Record your observations about the colour of the flame as you place the salt at the top of the flame.
- 10 Turn off the Bunsen burner carefully and let it cool down.
- 11 Dispose of the icy-pole stick and the used salt according to your teacher's instructions.

RESULTS

List your observations; for example, flame colour, sparkles, colour intensity. Some of the changes will not be very obvious, so observe carefully.

ANALYSIS

- 1 What safety procedures did you follow to light the Bunsen burner?
- 2 Did you have any problems working with the Bunsen burner? If so, what were the problems?
- 3 What do you think would have happened if you had used the orange flame instead of the blue flame?

3.8 Measuring in science

3.8

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define parallax error and meniscus
- ✓ identify common laboratory equipment, including thermometer, measuring cylinder, stopwatch and electronic balance
- ✓ label the meniscus on a diagram
- ✓ describe how to reduce parallax error
- ✓ describe how to correctly measure mass, volume, temperature, length and time.

GET THINKING

What do you already know how to measure?

- 1 How do you measure the amount of flour when baking a cake?
- 2 How do you measure how much you weigh?
- 3 How do you measure how tall you are?
- 4 How do you measure how long it takes you to get to school in the morning?
- 5 How do you measure how much food to feed your pet?
- 6 What else do you measure?



Quiz
Measuring in science

Video
Science skills in a minute: Measuring liquids

Science skills resource
Science skills in practice: Accurately measuring liquids

Measuring mass

Mass is the measure of the amount of matter in an object. It is measured in grams (g), kilograms (kg) or milligrams (mg). We measure mass with an electronic balance in a process called weighing (Figure 3.8.1).

In science, we usually need to put the object, or chemical, that we are weighing in a container (e.g. a beaker) to hold it. It is important that you don't include the mass of the container in the mass of the object. To avoid this error, the container is put on the balance first and the balance is zeroed or tared. This means that the balance is reset to a mass of zero. Then the object or chemical is added to the container.

mass

the amount of matter in an object, measured in kilograms (kg), grams (g) or milligrams (mg)



▲ FIGURE 3.8.1 The powder weighs 75.648 g.

Measuring the volume of liquids

volume

the amount of space occupied, measured in litres (L) or millilitres (mL)

Volume is described as the amount of space occupied by something. It is measured in litres (L) or millilitres (mL) – there are 1000 millilitres in 1 litre.

A measuring cylinder (also known as a graduated cylinder) is used to accurately measure the volume of a liquid. There are different-sized measuring cylinders. To get the most accurate measurements, use the smallest measuring cylinder that will hold the volume you need to measure.

When using any measuring apparatus, you need to ensure that it is on a flat, level surface. You also need to be at eye level with the measurement that you are reading on equipment such as measuring cylinders and thermometers. This reduces **parallax error**, which is the error that occurs when reading measurements from an angle.

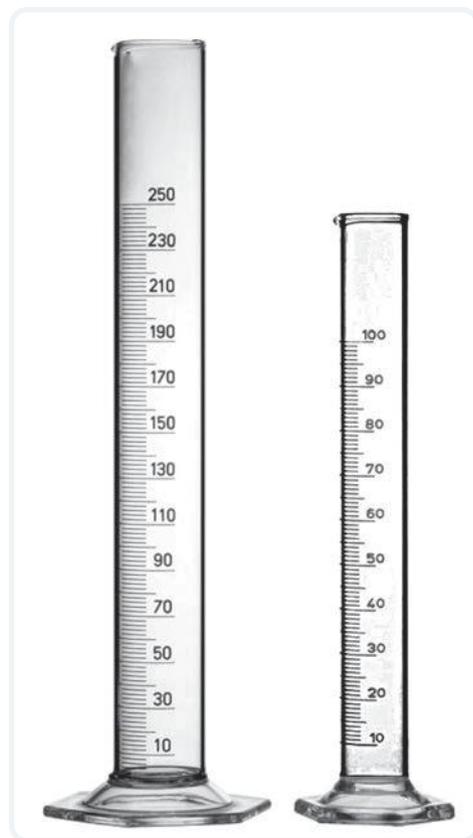
parallax error

an error in the reading of an instrument due to the viewing angle

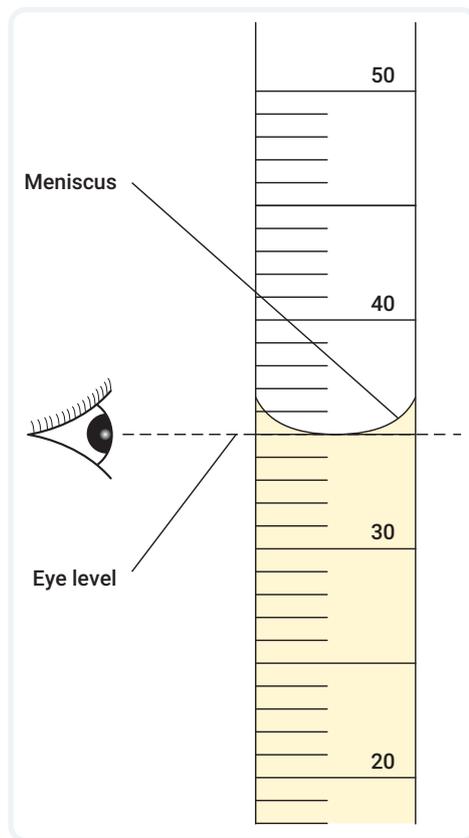
meniscus

the curved surface of a liquid when it is in a thin tube

When you look at the liquid in a measuring cylinder, you will notice that the surface is curved, not flat. This curved surface is called the **meniscus**. To measure the volume of liquid, read the measurement at the bottom of the meniscus (Figure 3.8.3).



▲ FIGURE 3.8.2 Measuring cylinders: use the smallest measuring cylinder that will hold the volume you need to measure to get the most accurate measurement.



▲ FIGURE 3.8.3 The meniscus on liquid in a measuring cylinder. The volume of this liquid is 35 mL.

Measuring temperature

Temperature indicates how hot or cold something is. We measure temperature in degrees Celsius ($^{\circ}\text{C}$) by using a thermometer or temperature probe.

A thermometer consists of a glass tube with a liquid inside and numbers marked on the outside (Figure 3.8.4). When the liquid gets hotter, it expands and moves up the tube. The temperature is the number at the top of the liquid.

A temperature probe is a digital thermometer (Figure 3.8.5). Most temperature probes connect to a device and give a read-out of the temperature.

temperature

how hot or cold something is, measured in degrees Celsius ($^{\circ}\text{C}$)



Deyan Georgiev/Shutterstock.com

▲ FIGURE 3.8.4 A thermometer is used to measure the temperature.



Science Photo Library / Alamy Stock Photo

▲ FIGURE 3.8.5 A temperature probe can also measure the temperature of a liquid in a beaker.

DATA SCIENCE



Learn more about errors in measuring continuous data in **Module 2.2**.

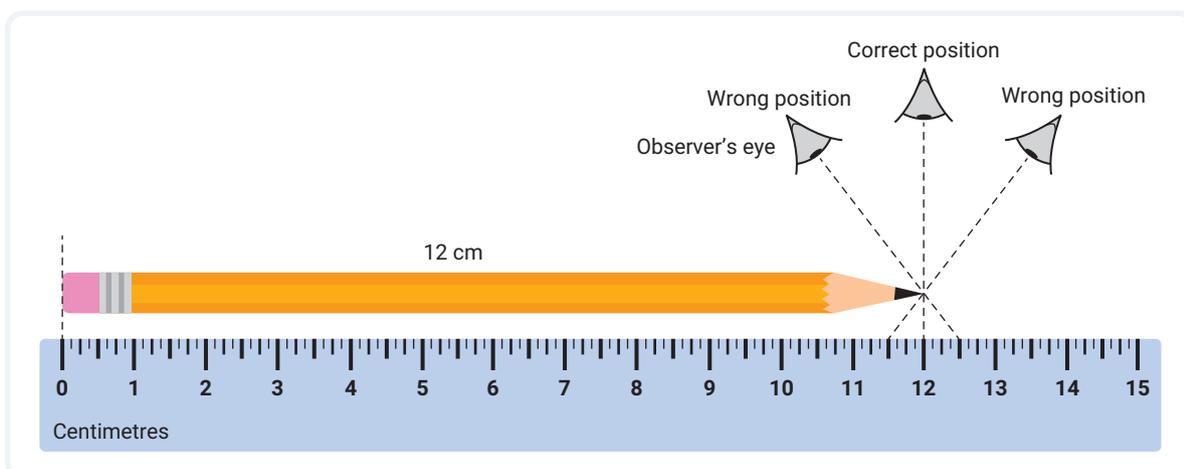
Measuring length

Length is the distance between two points, measured in metres (m), centimetres (cm) or millimetres (mm). There are 10 mm in 1 cm, 100 cm in 1 m, and 1000 mm in 1 m.

We use a ruler or measuring tape to measure the length of something by placing the zero mark at one end and then reading the number at the other end (Figure 3.8.6). You should look directly at the number to avoid parallax error and to get an accurate measurement.

length

the distance between two points, measured in metres (m), centimetres (cm) or millimetres (mm)



▲ FIGURE 3.8.6 Measuring the length of a pencil with a ruler

Measuring time

time
how long something takes, measured in hours (h), minutes (min) and seconds (s)

Time is how long something takes. It is measured in hours (h), minutes (min) and seconds (s). In the past, people used stopwatches to measure time. Now, most electronic devices such as phones and tablets can accurately measure time too.

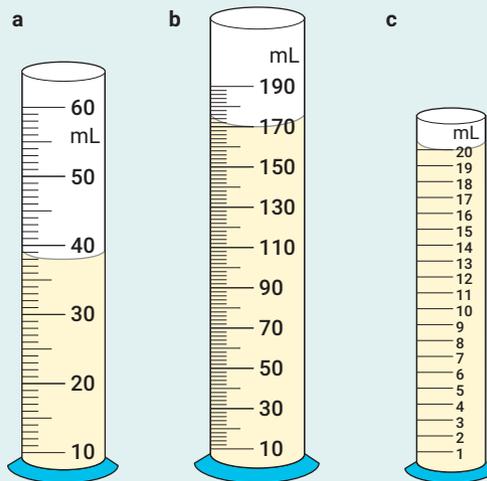
When measuring time in science, it is important that the timer is started and stopped at the right moments.

3.8 LEARNING CHECK

- 1 Copy and **complete** the table to link the equipment used to measure each quantity.

Quantity	Equipment	Unit
Length		
	Thermometer	
		grams
		millilitres
Time		

- 2 **Write** a set of instructions for a student to measure the height of a blade of grass.
 3 **State** the volume measured in each of the following pieces of equipment.



- 4 **Explain** why you would use a measuring cylinder and not a beaker to accurately measure the volume of a solution.
 5 During an experiment, a student turned on an electronic balance and placed a beaker on it. He then used a spatula to add sugar until the balance read 50.0 g. Was there 50.0 g of sugar in the beaker? **Explain** why or why not.
 6 Do you think a thermometer or a temperature probe is more accurate? **Justify** your answer.



Practise using laboratory equipment

SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ practising using laboratory equipment.

▶ Lab equipment tips

Here are some general pointers to help you use laboratory equipment correctly and safely.

- Check the materials listed in the Materials and equipment section. Do you have everything?
- Always ensure equipment is clean and dry before you use it.
- Take care when using fragile equipment, such as glassware.
- Let your teacher know if you accidentally damage or break equipment.
- Make sure you are careful when pouring and measuring liquids.



Video
Science skills in a minute: Lab equipment

Science skills resource
Science skills in practice: Using lab equipment

Safety

Broken glass can cut skin. Take care when using glassware. Report any breakages immediately and follow your teacher's instructions to clean it up. Put broken glass in the glass bin.

Wear safety glasses, gloves and lab coats at all times.

MEASUREMENTS WHEN ICE IS ADDED TO WATER

AIM

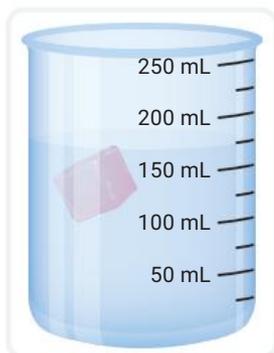
To use science equipment to measure the temperature change when an ice cube melts in water

MATERIALS AND EQUIPMENT

- water (approximately 150 mL)
- 2 × 250 mL beakers
- 200 mL measuring cylinder
- ice cube made from water with food dye
- electronic balance
- thermometer or temperature probe
- stopwatch or timer on a device

PROCEDURE

- 1 Use a measuring cylinder to measure 150 mL of water. Record this volume in a results table like the one on the next page.
- 2 Pour the water into a beaker.
- 3 Use the thermometer (or temperature probe) to measure the temperature of the water. Record the temperature in the results table.
- 4 Place the second beaker on the electronic balance and press zero (or tare) so that the reading is 0.00 g.
- 5 Add one ice cube to the beaker to measure its mass. Record the mass in the results table.
- 6 Prepare the stopwatch (or timer) so that it is ready to start timing.
- 7 Add the ice cube to the water and start the stopwatch (or timer) (Figure 3.9.1).
- 8 Stop the stopwatch (or timer) as soon as the ice has melted. Record this time in the results table.
- 9 Use the thermometer (or temperature probe) to measure the temperature of the water when the ice cube has melted. Record this final temperature in the results table.
- 10 Pour the water down the sink and rinse your equipment before packing it away.



◀ **FIGURE 3.9.1** The coloured ice cube is added to the water.

RESULTS

- 1 Copy and complete the results table below.
- 2 List five observations that you made during the experiment.

Description	Measurement
Volume of water (mL)	
Initial temperature of water (°C)	
Mass of ice cube (g)	
Time for ice cube to melt (mins)	
Final temperature of water (°C)	

ANALYSIS

- 1 Why do you think the ice cube melted?
- 2 How many degrees Celsius did the temperature of the water change by?
- 3 What do you think would have happened if:
 - a you had used a smaller volume of water?
 - b the ice cube had a bigger mass?
 - c the ice cube had been crushed?
- 4 What steps did you take so that your measurements were as accurate as possible?

CONCLUSION

What did you learn in this activity?

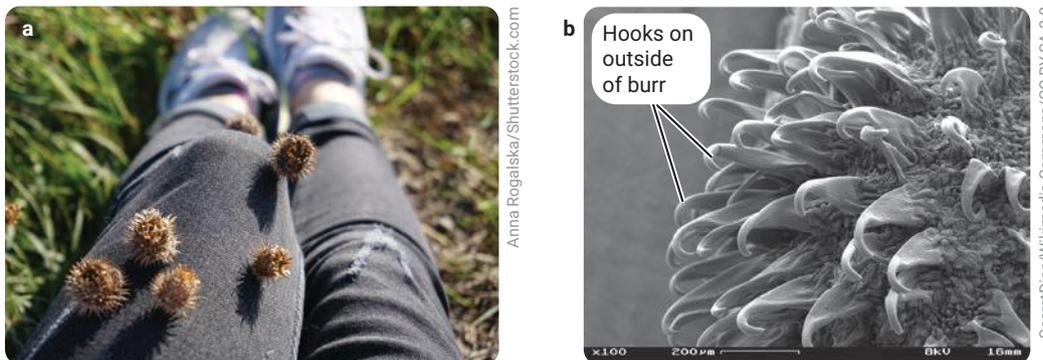
3.10 From burrs to Velcro

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

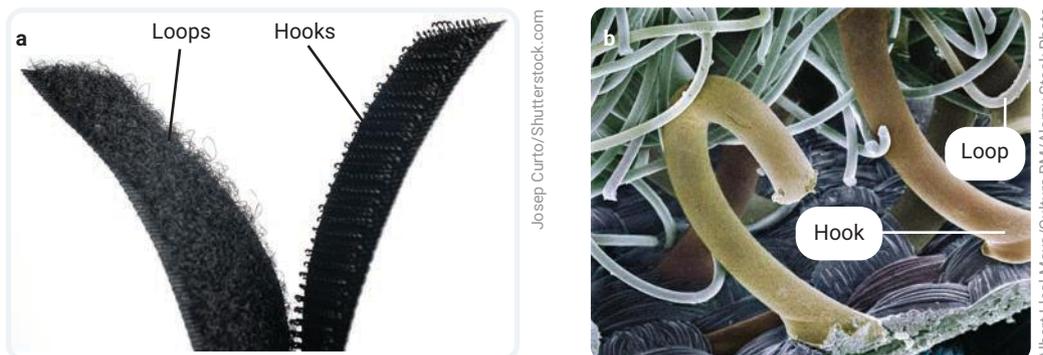
- ✓ explain how looking at things from a different perspective can lead to scientific advances.

After a hike in 1941, Swiss electrical engineer George de Mestral came home with burrs stuck to his clothes. Rather than being annoyed, he wondered whether the stickiness of burrs could be adapted to be useful.

De Mestral looked at the burrs under a microscope and saw that they had hooks that latched onto clothes (Figure 3.10.1b). He then spent many years trying to use this structure to make a material with hooks on one side that could latch onto loops on the other side. De Mestral finally succeeded, with Velcro becoming available in the early 1960s. Since then, other companies have produced similar products, which are known as hook and loop fasteners.



▲ FIGURE 3.10.1 (a) Burrs stick to clothes and are hard to remove. (b) Under an electron microscope it can be seen that burrs have hooks that cling to fabric.



▲ FIGURE 3.10.2 (a) Velcro is made up of hooks and loops. (b) Velcro under an electron microscope, showing how it has hooks on one side that hold on to loops on the other side.

Visit the weblinks to learn more about the invention of Velcro.

3.10 LEARNING CHECK

- 1 Use a dictionary (either online or a book) to find the definition of 'mimicry'. How is the development of Velcro an example of mimicry?
- 2 What other inventions are an example of mimicry?



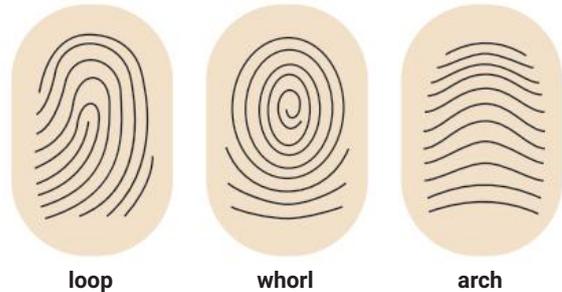
Weblinks
 Live Science: Velcro
 Inventing Velcro
 Time: History of Velcro

As a biometrician, you are called to the crime scene of a robbery. A window is broken, and many drawers are open around the house. Some jewellery and a laptop are missing. The chief of the forensic team wants you to send the fingerprints to a fingerprint analysis unit for comparison with records in a database they keep.

As you dust the furniture to retrieve the fingerprints, you notice some hairs on the floor beside the bed. You collect them carefully, and send the specimen to the DNA analysis unit.

You must do an in-depth study of the collected fingerprints and meet with the DNA analysis unit to identify the robber.

Fingerprint patterns



1 Connect what you've learned

In this chapter, you've learned how scientists work together and follow the working scientific processes.

To complete this activity, you'll need to first do some research about how fingerprint analysis is done in a forensic investigation.

- How are you going to compare the fingerprints you collected with the records in the crime unit database?
- What are the observed characteristics of fingerprints?
- What other information do you need from the crime scene to complete your investigation?

2 Check your thinking

You will use your critical thinking skills to analyse the samples and compare them with the profiles in the crime files.

- What criteria would you use to compare the fingerprints?
- What observations and measurements would need to be made to search for a match? How would this help you identify the robber?
- What challenges might you encounter in this investigation?

4 Communicate

Create a scientific report with your findings, with an aim, method, results, analysis and conclusion. Keep in mind that the report has to be presented to the police crime unit.

3 Get into action

Use your answers from steps 1 and 2 to develop a plan to analyse your samples, including the one you sent to the DNA unit.

4

Space science

4.1 Earth, Sun and Moon (p. 132)

Earth orbits the Sun and the Moon orbits Earth.

4.2 WORKING SCIENTIFICALLY: Mathematical models (p. 134)

Modelling the behaviour of Jupiter's moons

4.4 Earth's revolution around the Sun (p. 138)

Earth revolves around the Sun once every year.

4.3 The rotation of Earth (p. 136)

Earth rotates on its axis once every day.

4.5 Changes in models of space (p. 141)

Models of space have been changed or replaced as new scientific evidence is accepted.

4.6 Seasons (p. 144)

Seasons are caused by the tilt of Earth's axis as Earth moves around the Sun.

4.8 Phases of the Moon (p. 148)

Phases of the Moon occur when we see different amounts of light reflected from the Moon.

4.7 WORKING SCIENTIFICALLY: Observing with physical models (p. 147)

Modelling Earth's tilt and illumination

4.9 WORKING SCIENTIFICALLY: Using physical models to explain phenomena (p. 151)

Modelling phases of the Moon

4.10 Eclipses (p. 152)

Eclipses are caused when light from the Sun is blocked by a planet or satellite.

4.11 Tides (p. 156)

Tides are the result of gravitational attraction on the ocean by the Moon and the Sun.

4.12 ABORIGINAL AND TORRES STRAIT ISLANDER SCIENCE CONTEXTS: Knowledge of Moon phases and tides (p. 159)

Aboriginal and Torres Strait Islander Peoples have observed the night sky and built a wealth of astronomical knowledge over thousands of years.

4.13 SCIENCE IN CONTEXT: Australian advances in astronomy (p. 162)

Australian scientists contribute to our knowledge of the universe.



▲ FIGURE 4.0.1 Sunrise

Each day, as the Sun rises, it causes changes on Earth's surface.

- ▶ Would days and nights on Earth be different if Earth was a little further away from the Sun?
- ▶ How would the oceans be different if Earth had two moons, like Mars?
- ▶ What if the Moon was further away from Earth than it is now? What would change on Earth?

What information do you think you need to answer these questions?

#4 DIVE INTO SCIENCE!

At the end of this chapter, you will complete the Science in Depth Study #4. You can use the information you learn in this chapter to complete the project.

Assessments

- Prior knowledge quiz
- Chapter review questions
- End-of-chapter test
- Depth study: Presentation

Videos

- Science skills in a minute: Modelling data (4.2)
- Video activities: What is an orbit? (4.1); Why does Earth have seasons? (4.6); What are eclipses? (4.10); The Moon and spring tides (4.11); SKA (4.13)

Science skills resources

- Science skills in practice: Modelling data (4.2)
- Extra science investigations: Modelling eclipses (4.10); The effect of the Moon on tides (4.11)

Interactive resources

- Quizzes: Earth rotation (4.3); Who was Galileo? (4.5)
- Crossword: Moving Earth (4.4)
- Match: Phases of the Moon (4.8)

4.1 Earth, Sun and Moon

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ identify the orbits of Earth and the Moon
- ✓ describe the position of Earth, the Sun and the Moon relative to each other.



Video activity
What is an orbit?

GET THINKING

How do the Sun, Earth and the Moon move relative to each other? Draw a labelled diagram to show your answer. How confident are you in your answer? Explain why you are, or are not, confident.

Planets and moons

planet

a natural body that orbits a star

orbit

the regular, repeating path an object takes in space around another object

satellite

an object in orbit around a larger object

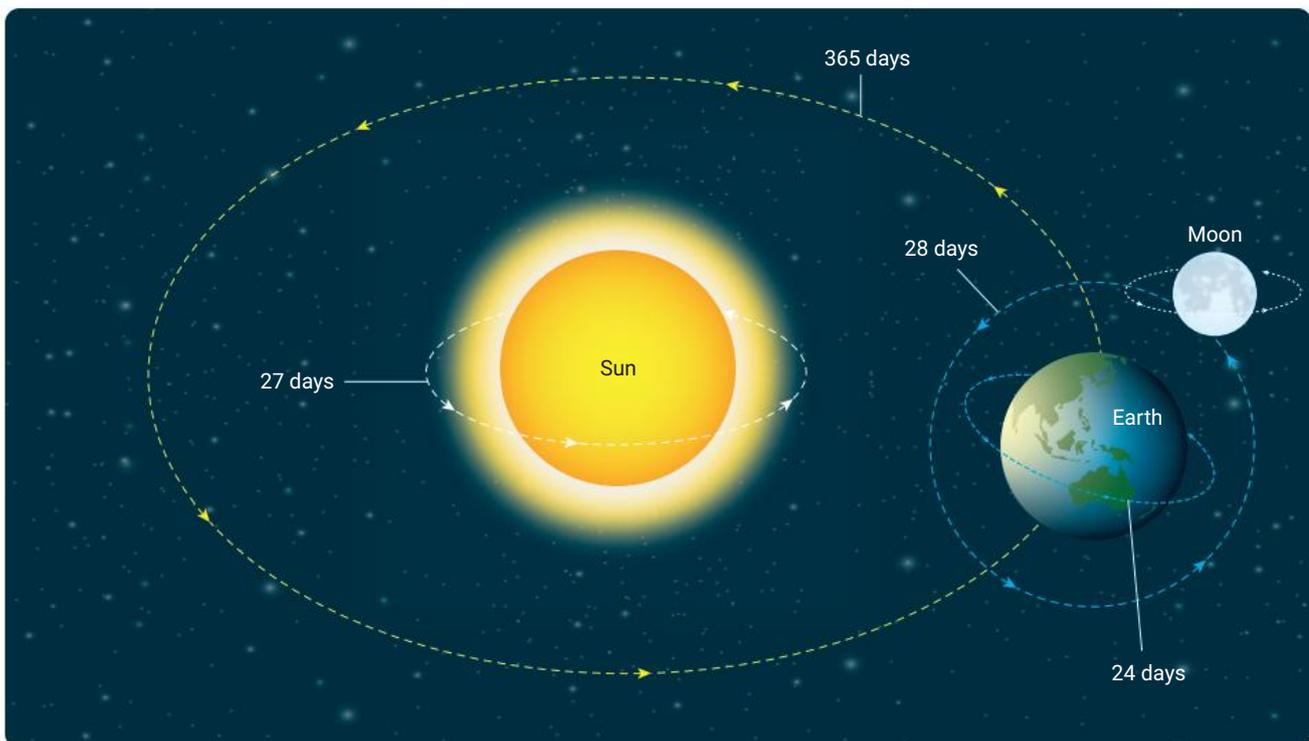
moon

a natural satellite of a planet

How are planets and moons different from each other? A **planet** is a natural body that travels around a star in a regular, repeating path called an **orbit**. Earth is a planet because it orbits the star we call the Sun. Other planets that also orbit the Sun are Mercury, Venus, Mars, Jupiter, Saturn, Uranus and Neptune.

Any object in orbit around a larger object is called a **satellite**. Therefore, Earth is a satellite of the Sun. If the object is a natural satellite of a planet, it is called a **moon**. There are more than 200 moons in our solar system. Earth only has one moon, Jupiter has 95 moons, but Mercury and Venus do not have any moons. Because Earth only has one moon, we refer to it as ‘the Moon’ (Figure 4.1.1).

In summary, a planet is a satellite that orbits the Sun and moons are satellites that orbit planets.



▲ FIGURE 4.1.1 The motion of the Sun, the Moon and Earth. The Moon is a satellite of Earth and Earth is a satellite of the Sun.



▲ **FIGURE 4.1.2** The Moon. As the Moon orbits Earth, it keeps the same face towards Earth (you will learn more about this in Module 4.8).



▲ **FIGURE 4.1.3** Earth and the Moon are a long way from each other.

Distances in space

The distances involved in orbits are extremely large. The average distance between the Moon and Earth is 384 400 km. The average distance between Earth and the Sun is 149 600 000 km – 389 times greater than the distance between the Moon and Earth. It is very hard for us to understand such large distances. Figure 4.1.3 shows the Moon and Earth together; however, the image was taken about 541 000 km from Earth!

4.1 LEARNING CHECK

- 1 **Define** orbit.
- 2 **Describe** the orbits of Earth and the Moon.
- 3 **Draw** a labelled diagram to show the orbits of Earth and the Moon.
- 4 **Create** an animation or model to show the orbits of Earth and the Moon.
- 5 **Explore** the moons of other planets. **Summarise** the number of moons for each planet in a table.
- 6 **Explain** why it may be difficult to create a diagram that accurately shows the distances between the Sun, planets and the Moon.



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ analysing a model to identify trends and generate predictions
- ▶ identifying patterns and relationships in scientific data.

A scientific model is a simplified representation of something complicated.

Scientific models can be:

- physical models made with materials, such as a model of the Moon circling Earth
- mental models, such as ideas like the particle model of matter
- mathematical models, with equations and graphs to show relationships, such as a weather simulation run on a computer.

Scientists use mathematical models to understand processes that occur in the world. A mathematical model describes an object or process using mathematical equations and representations. The data used to create mathematical models is continuous data, such as time, distance, force and other physical properties.

A first step in creating a model is to plot the relationship between relevant variables on a graph. In Chapter 2, you learned that if you can draw a line of best fit through the data points, you can use it to make predictions.

Remember that because data measurements contain errors, data points may not lie exactly on the line of best fit. Predictions can be made from a line of best fit for the area covered by the data you have plotted. Module 2.8 explains why making predictions outside the range of your data can be misleading.

MODELLING THE BEHAVIOUR OF JUPITER'S MOONS

At least 95 moons orbit Jupiter. Some moons have orbital periods measured in hours while others take almost three Earth years to orbit Jupiter.

AIM

To model the relationship between a moon's distance from Jupiter and its orbital period.

MATERIALS AND EQUIPMENT

- access to the internet
- a spreadsheet app, if possible
- a sheet of graph paper

PROCEDURE

- 1 Make a table similar to the table on the next page.
- 2 Research the following moons to complete the table: Adrastea, Amalthea, Ananke, Callisto, Europa, Ganymede, Io and Lysithea.
- 3 Plot a graph of the orbital period (vertical axis) against each moon's distance from Jupiter (horizontal axis). Draw a curved line through the points.



Video
Science skills
in a minute:
Modelling data

**Science skills
resource**
Science skills
in practice:
Modelling data

RESULTS

Your table should look similar to the example table below.

Remember to add enough rows for eight moons.

Moon name	Diameter of the moon (km)	Distance from Jupiter (millions of km)	Orbital period (Earth days)	Year of discovery

ANALYSIS

- Describe the relationship between orbital period and distance from Jupiter.
- Himalia is another moon of Jupiter, with a period of 251 Earth days.
 - Use your line of best fit to predict how far from Jupiter Himalia orbits.
 - Research the actual orbital distance of Himalia. How close was your prediction?
- Evaluate whether the graph has the properties of a good scientific model.

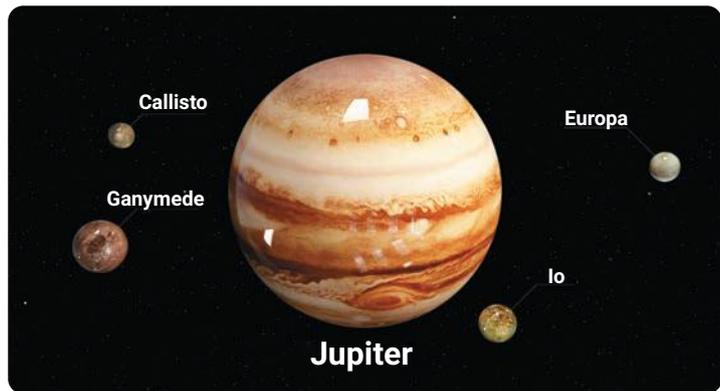
CONCLUSION

Describe the relationship between a moon's distance from Jupiter and its orbital period.

HAKAN AKIRMAK VISUALS/Shutterstock.com



▲ FIGURE 4.2.1 Ganymede is Jupiter's largest moon.



▲ FIGURE 4.2.2 An artist's impression of Jupiter's four biggest moons orbiting the planet

Victor Josan/Shutterstock.com

4.3 The rotation of Earth

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe the rotation of Earth on its axis
- ✓ explain the cause of daytime and night-time.

GET THINKING

How are day and night related to the movement of the Sun and stars? Scan the headings and images in this module and note down what you think the module is about.

Why we have daytime and night-time



Pekka Parvianen/Science Photo Library

▲ FIGURE 4.3.1 As Earth spins, the Sun appears to move across the sky during a day. The height of the path varies during the year and is different depending on how close you are to Earth's poles.

Planets have an imaginary line through their centre that they spin, or rotate, around. This is called the **axis**, or rotational axis. Earth's axis has a **tilt** of 23.5° (Figure 4.3.2).

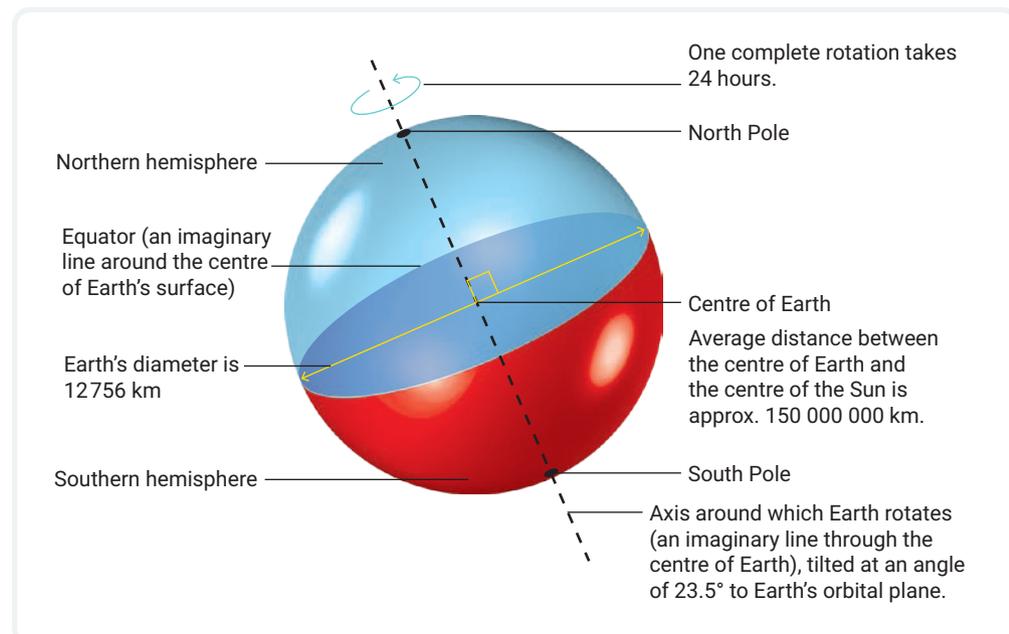
We have **daytime** and **night-time** because Earth rotates about its axis. As Earth turns, a place that was in darkness moves into the light of the Sun. In this lit area, it is daytime. In the shadow on the other side of Earth, it is night-time. Earth spins from west to east, which is why the Sun appears to rise in the east and set in the west.

axis
an imaginary line that an object spins around

tilt
sloping away from the vertical

daytime
the time of day between sunrise and sunset

night-time
the time of day between sunset and sunrise



► FIGURE 4.3.2 Earth's geometry

A day

When a planet or moon spins once on its axis, we say it has made a **rotation**. The time for Earth to make a single rotation on its axis (24 hours) is called a **day**. Other planets spin at different speeds, so their day lengths are different. For example, Jupiter, although many times larger than Earth, spins faster and only takes 9 hours and 56 minutes to rotate once on its axis.

rotation

the motion of an object around an internal axis

day

the time it takes for a planet to make one rotation around its axis

The rotating Earth

Earth rotates on its axis once every 24 hours. We do not notice Earth spinning because everything around us, including the atmosphere, is spinning with Earth. The surface of Earth at the equator is travelling at a speed of 1600 km/h! The speed decreases as you move to the poles because the distance travelled becomes shorter. To the south, in Sydney, the surface spins at only about 1400 km/h.

Earth's tilt and day length

The length of daytime and night-time depends on where you are on Earth and the time of the year. Near the equator, the length of daytime is about 12 hours and 7 minutes and varies by only 2 minutes throughout the year. As you move south or north, the length of daytime and night-time changes. In the Arctic and Antarctica, daytime and night-time can be as long as 24 hours. During winter, daytimes are shorter than they are in summer. Night-times are longer in winter and shorter in summer. You will learn more about the cause of this later in the chapter when we examine the seasons.



◀ **FIGURE 4.3.3** An Antarctic sunset. In mid-winter, the Sun does not rise for a couple of weeks.

4.3 LEARNING CHECK

- 1 **State** the angle of tilt of Earth's axis.
- 2 **State** how long it takes Earth to rotate once on its axis.
- 3 How is daytime different from a day?
- 4 How does Earth's rotation cause daytime and night-time?
- 5 **Explain** two factors that affect the length of day and night.
- 6 **Research** the longest and shortest day length where you live. **Compare** these to a place:
 - a further north or south.
 - b on the opposite side of Australia.

4.4 Earth's revolution around the Sun

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ state the time it takes Earth to orbit around the Sun
- ✓ explain why the orbital time depends on the distance of Earth from the Sun.

GET THINKING

Scan the key words in this module and make a crossword or find-a-word puzzle with these terms to share with other students in your class.

revolution

the path an object travels as it moves around another object

period

the time it takes for a satellite to complete one orbit or revolution

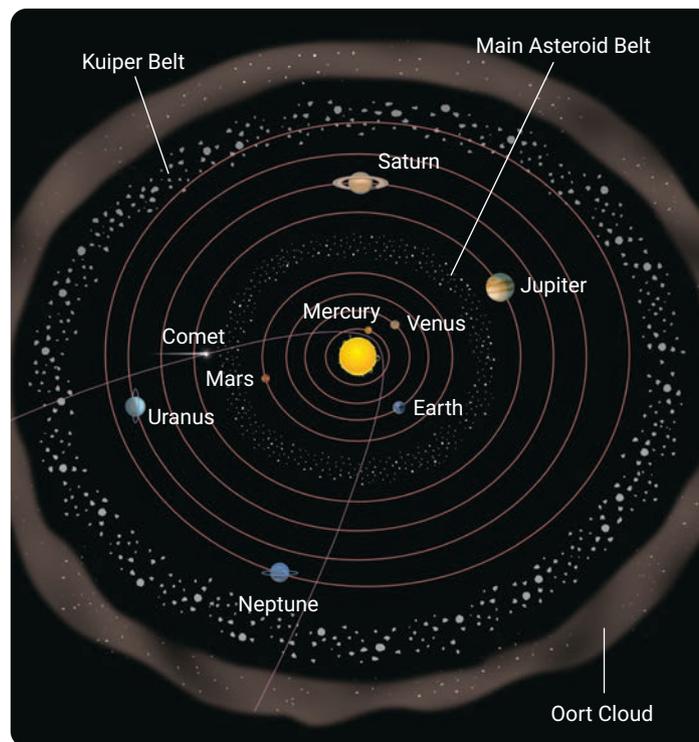
solar year

the time it takes for a planet to revolve once around the Sun

In Module 4.1, you learned that Earth moves around the Sun. The term **revolution** describes the orbital motion of a satellite, such as Earth, around a large body, such as the Sun. When Earth orbits the Sun, we say Earth revolves around the Sun, just as the Moon revolves around Earth. The time it takes for a satellite to complete one orbit or revolution is called the **period**. The Moon's period is 27.3 days because it takes 27.3 days to make one revolution around Earth. When the satellite is a planet orbiting the Sun, the period is called a **solar year**. Therefore, the period and solar year for Earth is 365.24 days because this is how long it takes to make one revolution around the Sun (Figure 4.4.1).



Interactive resource
Crossword: Moving Earth



▲ FIGURE 4.4.1 A two-dimensional model of the solar system, showing the revolution of the planets around the Sun. The positions of the orbits and the sizes of the planets are not to scale.

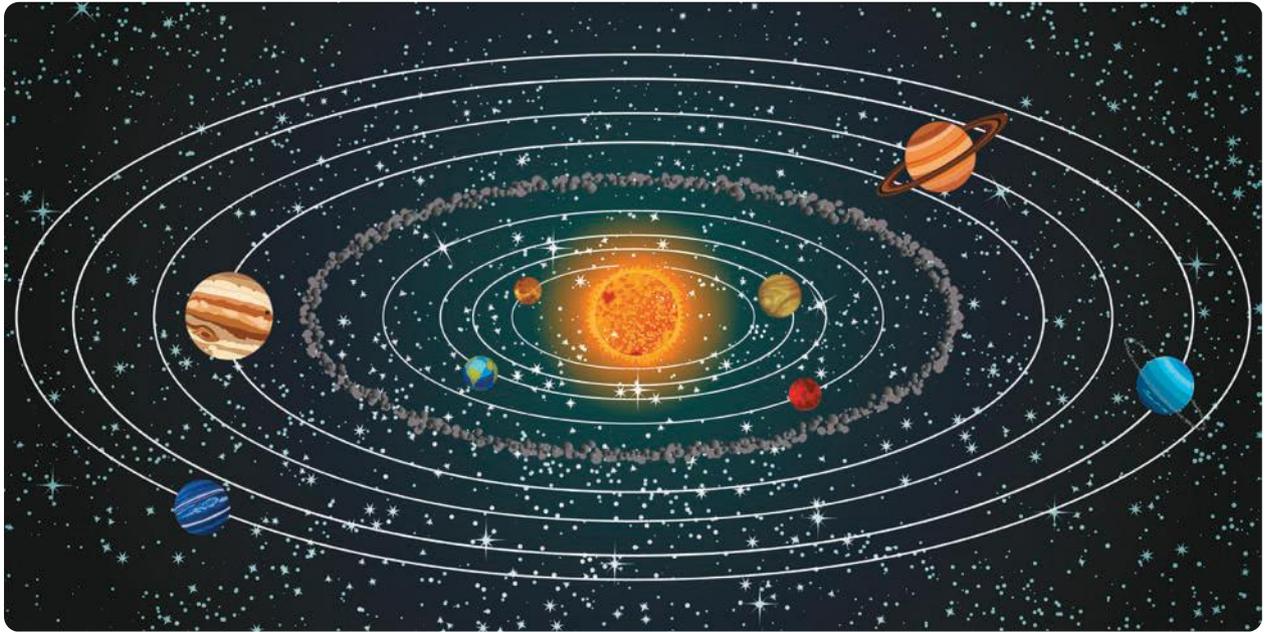
orbital plane

a surface that contains the orbit of a body

ecliptic

the path travelled by the Sun and planets as seen from Earth

Other planets orbit the Sun in a similar way to Earth. If you were to connect the centre of the Sun to Earth, over a year the line would sweep out a flat disc-shaped surface (Figure 4.4.2). The imaginary surface that the orbit lies in is called the **orbital plane**. All the planets of our solar system orbit with similar orbital planes to Earth. Because Earth's axis is tilted to the orbital plane, the planets and the Sun seem to travel along a path across the sky. This path is called the **ecliptic**.



▲ FIGURE 4.4.2 The planets orbit the Sun with similar orbital planes. The orbits and planets are not to scale.

The time for one revolution is different for each planet. Table 4.4.1 shows how the time for a revolution (hence, a solar year) increases as the distance from the Sun to a planet increases. This distance is measured in **astronomical units** (AU), where one astronomical unit is the average distance of Earth from the Sun. This is equivalent to approximately 150 million kilometres.

The closer an object is to the Sun, the shorter its orbit and the faster it must travel to stay in orbit. If it were to slow down, it would spiral into the Sun. Mercury is the closest planet to the Sun and has the greatest speed at 47.9 km/s. Neptune is the outermost planet and travels the furthest at a leisurely 5.4 km/s. Earth, travelling closer to the Sun than Neptune, moves at 29.8 km/s. The combination of greater speed and less distance results in a shorter period for planets closer to the Sun.

astronomical unit
the average distance from the centre of Earth to the centre of the Sun, equivalent to 149.6 million kilometres (abbreviation AU)

▼ TABLE 4.4.1 The rotational period and distance from the Sun of the planets

Planet	Distance from the Sun (AU)	Time for one revolution (solar year)
Mercury	0.39	0.24
Venus	0.72	0.62
Earth	1	1
Mars	1.52	1.88
Jupiter	5.20	11.9
Saturn	9.58	29.4
Uranus	19.2	83.7
Neptune	30.0	163.7

Orbit calculations

- 1 Vesta is an asteroid that orbits the Sun in the asteroid belt between Mars and Jupiter. It has an average diameter of 525 kilometres. Can you predict the rotational period of Vesta?



▲ FIGURE 4.4.3 Vesta

- 2 Phobos and Deimos are the moons of Mars. Deimos orbits Mars 2.5 times further away than Phobos. Which moon has the shortest orbit?



▲ FIGURE 4.4.4 Phobos and Deimos

4.4 LEARNING CHECK

- 1 **Define** revolution.
- 2 **State** how long it takes Earth to complete one revolution of the Sun.
- 3 **Define** period.
- 4 If Earth orbited closer to the Sun, **explain** how the length of a year would be different.
- 5 Which planet has:
 - a the smallest orbital period?
 - b an orbital period closest to Earth's rotational period?
- 6 **Explain** the relationship between a planet's orbital period and its distance from the Sun.
- 7 **Graph** the rotational period and distance from the Sun in Table 4.4.1 on a piece of graph paper with a curved line of best fit. What do you notice about the periods of the inner planets (Mercury to Mars) compared with the periods of the outer gas giants (Jupiter to Neptune)?

4.5 Changes in models of space

4.5

BY THE END OF THIS MODULE YOU WILL BE ABLE TO:

- ✓ compare historical and current solar system models to show how models are modified or rejected as new scientific evidence is accepted.

GET THINKING

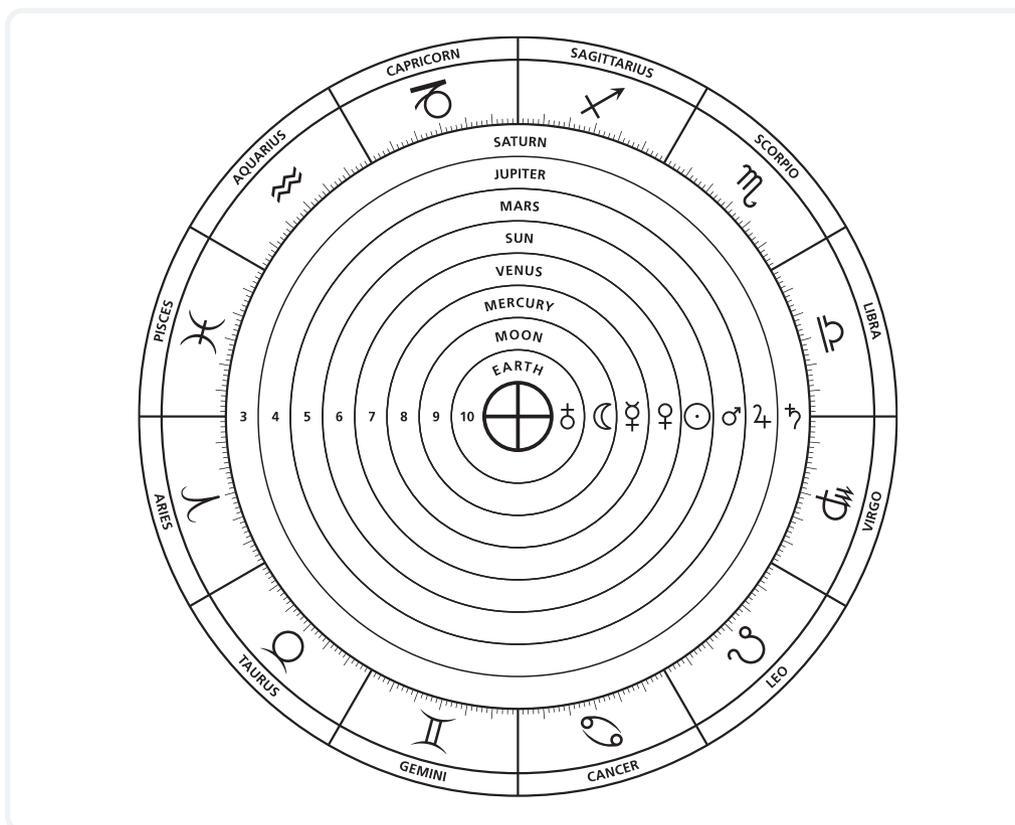
How many planets can you observe in the night sky without a telescope? How did people imagine the solar system before telescopes were invented? Make a list of the things you would include in a model of the solar system if discoveries with a telescope were not possible.



Quiz
Who was Galileo?

An Earth-centred model

The way we think of the solar system today, with the planets moving around the Sun, is something we take for granted. But models of the solar system and its place in the universe have changed over time. Figure 4.5.1 shows a model of the universe that was widely accepted for more than a thousand years.



Peter Hermes Furian/Shutterstock.com

▲ FIGURE 4.5.1 Ptolemy's model of the universe put Earth at the centre and was thought accurate for more than a thousand years.

The model is named after the astronomer Ptolemy, who lived in Egypt about 1900 years ago. It is called a **geocentric** model because Earth is in the centre. There are only five planets circling Earth, and the Sun, Moon, Earth and planets are surrounded by the star constellations of the zodiac. The number of known planets only increased with the use of the telescope, about 400 years ago.

geocentric
centred on Earth

Ptolemy studied and measured the position of the Sun, planets, Moon and stars with great care. The objects in the sky seemed to move in circles around Earth so Ptolemy thought of Earth as the centre of the universe. When Ptolemy published 20 years of his own measurements, together with those of others, his theory about how the solar system worked became established as the best explanation. Ptolemy's model had practical value for navigators at sea and on land, who used planetary positions to work out where they were.

A Sun-centred model

Not everyone thought of the universe in the same way as Ptolemy. Born 400 years earlier than Ptolemy, Aristarchus of Samos believed in a Sun-centred universe (a **heliocentric** model). He also understood that stars are very distant from Earth and wondered if they might be like the Sun.

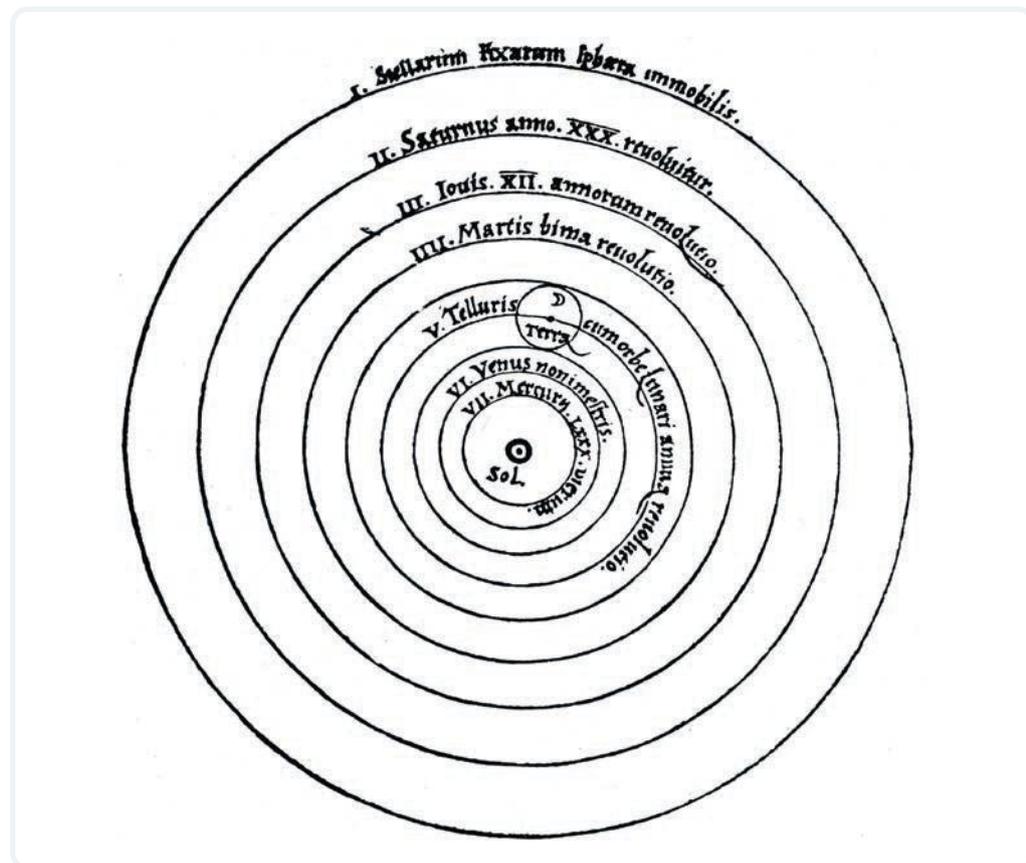
Then centuries later, in the mid-1500s in Poland, a man called Nicolaus Copernicus developed a heliocentric model like that of Aristarchus (Figure 4.5.2). His model was composed of circular orbits like Ptolemy's but was published with updated data. Like Ptolemy's model, planets moved in circular orbits and Saturn was the outermost planet.

heliocentric
centred on the Sun

DATA SCIENCE



Learn more about how scientists use data to create and improve scientific models in **Modules 2.9 and 2.10**.



▲ **FIGURE 4.5.2** The model of the universe that Copernicus suggested had the Sun (labelled 'Sol') at the centre.

Pictorial Press Ltd / Alamy Stock Photo

Technology and new ideas

New technologies generated new data that helped explain the solar system. The use of the telescope for astronomy (Figure 4.5.3), instruments that measured the positions of planets more precisely, and developments in mathematics all helped to establish the heliocentric model of the universe.

Galileo Galilei used the telescope to observe the phases of Venus and to see that Jupiter had its own moons. These observations contradicted the ideas of Ptolemy's model. Johannes Kepler, in the early 1600s, used accurate data to show that planets do not move in circular orbits but in paths known as **ellipses**. Kepler's work showed that a modified heliocentric model predicted planetary motion more accurately than earlier models. In 1687, Isaac Newton proposed a mathematical model to describe **gravity** and explain why planets orbit the Sun, why the Moon orbits Earth and the nature of tides.

Later improvements in telescopes led to the discovery of the most distant planets in our solar system and of distant galaxies. Today we know that our solar system is one of 3200 in the Milky Way galaxy, thanks to observations from space telescopes such as the James Webb Space Telescope.



▲ **FIGURE 4.5.3** An early telescope. The development of telescopes and other instruments led to more accurate measurements.

ellipse

a regular oval shape

gravity

a force applied by one mass on another mass

4.5 LEARNING CHECK

- 1 **Define** the term geocentric.
- 2 **List** three similarities between the geocentric model of Ptolemy and the heliocentric model of Copernicus.
- 3 **List** three technologies that have contributed to our modern understanding of the solar system.
- 4 **Describe** two differences between the geocentric model of Ptolemy and the heliocentric model of Copernicus.
- 5 **Draw** diagrams of heliocentric and geocentric models of our solar system, showing the Sun, Earth, the Moon and two planets.

4.6 Seasons

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe seasons and how they vary in different parts of Australia
- ✓ explain how seasons on Earth are caused by Earth's tilt and the relative positions of the Sun and Earth.



Video activity
Why does Earth have seasons?

GET THINKING

What is your favourite season? Why do you like it? In this module, we will look at the relationship between the tilt of Earth, heating and seasons. Write down what you think the source of heating is and why we have different seasons.

The nature of seasons

The weather, length of days and the behaviour of living things change during a year. A period of time characterised by particular weather and day length is called a **season**. In southern Australia, people often recognise four seasons: spring, summer, autumn and winter (Figure 4.6.1a) Tropical northern Australia experiences a dry season and a wet season, which have very different characteristics from seasons in southern areas of Australia (Figure 4.6.1b).

season

a period of time characterised by weather and day length

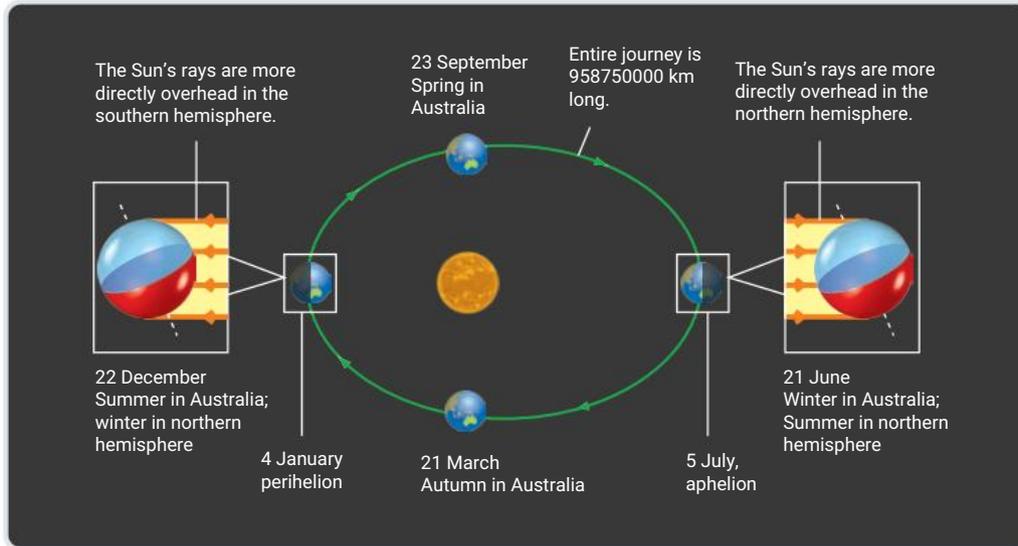


▲ **FIGURE 4.6.1** (a) Autumn in southern Australia may be colourful because of the changing leaf colours of trees that have been imported from other parts of the world. (b) Rain and thunderstorms are a feature of the wet season in northern Australia.

Why seasons occur

Seasons result from the tilt of Earth's rotational axis. Earth's axis is tilted at 23.5° to the vertical. This means that the sunlight and heating by the Sun are different in the northern and southern hemispheres. If there were no tilt to Earth's axis of rotation, both hemispheres would be warmed equally. The Sun would always appear to be above the equator and the surface would receive the same amount of light and heat each day. There would be no seasons. However, this is not the case.

As Earth orbits the Sun, the axis continues to point in the same direction (Figure 4.6.2). During an Australian summer, the axis in the southern hemisphere is pointing towards the Sun. Six months later, in winter, the axis is pointing away from the Sun. During spring and autumn, Earth's axis lines up with Earth's direction of travel and so both hemispheres receive similar amounts of light.

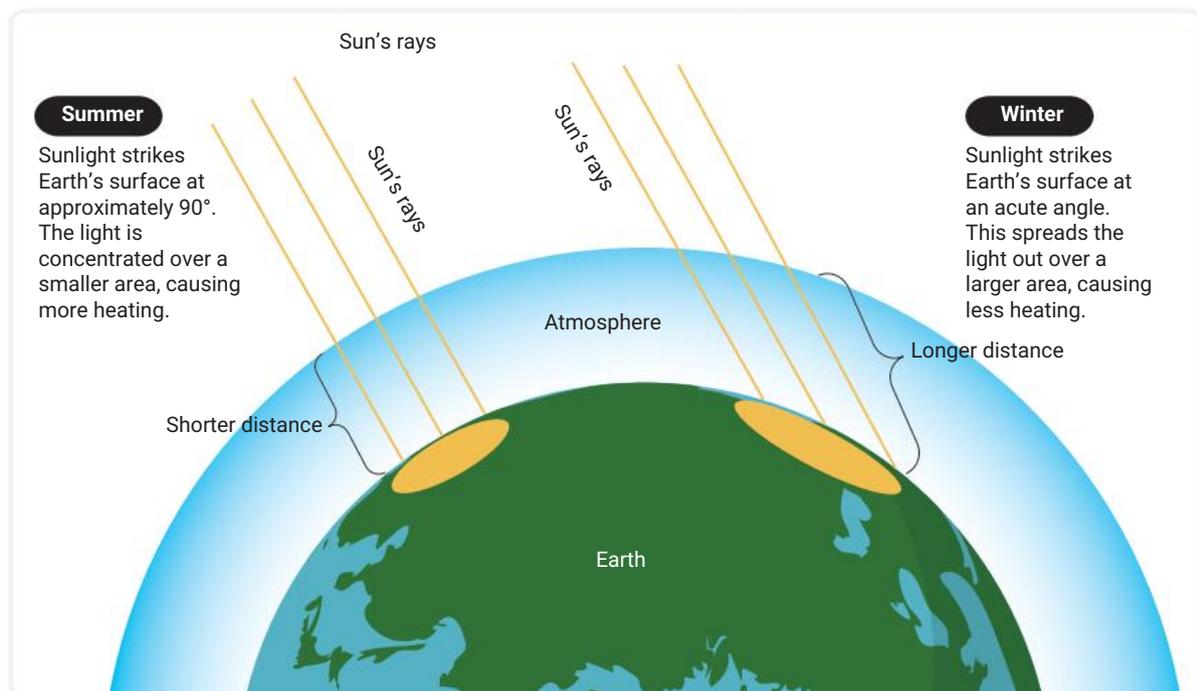


▲ FIGURE 4.6.2 Seasons are caused by Earth's tilt.

During summer, the Sun appears higher in the sky and sunlight reaches Earth nearly at a right angle to Earth's surface. This means the Sun's rays travel a shorter distance through the atmosphere and are concentrated over a smaller area (Figure 4.6.3). The more concentrated light and longer days heats the surface more than in winter.

In winter, the Sun's incoming rays are at more of an acute angle. The light travels a longer distance through the atmosphere and the sunlight is spread over a larger area. The less concentrated light and shorter days means the surface warms less than in summer.

During spring and autumn neither hemisphere is tilted towards the Sun. Therefore, the weather conditions are between the cold of winter and the warmth of summer.



▲ FIGURE 4.6.3 The angle of sunlight affects the area lit and the amount of heating.

In northern Australia, there is less variation in the angle of the Sun's incoming rays throughout the year. This means that the seasons are not as varied as they are further south. From May to September, there is less rainfall and the land dries. This is known as the dry season. From October to April, moist air flows inland from the sea; the air rises to form clouds and rain is produced. This is known as the wet season.

☆ ACTIVITY

The longest day of summer

The summer solstice is the day in the year when the Sun travels the longest path. It also reaches its highest point in the sky. The summer solstice for the southern hemisphere occurs usually on 22 December, but it may occur a day earlier or later. The summer solstice is the longest day of the year.

Something special occurs on the summer solstice at a line of latitude called the Tropic of Capricorn. When the Sun is at its highest, it casts no shadow – it is directly overhead.

Table 4.6.1 shows information about places on Australia's east coast and in Antarctica on 22 December near midday.

▼ **TABLE 4.6.1** The length of shadow of a 1 m stick at different places near midday on 22 December

City or place	Latitude (degrees south of the Equator)	Angle of the Sun above Earth's surface (degrees)	Length of the day (hours)	Shadow length of a vertical 1 m stick (m)
Rockhampton	23.38 (Tropic of Capricorn)	90.0	13.6	0
Brisbane	27.47	85.4	13.9	0.08
Sydney	33.87	73.7	14.4	0.29
Melbourne	37.82	67.3	14.8	0.42
Hobart	42.88	65.4	15.4	0.46
East Antarctica	86.10	32.3	24.0	1.56

Questions

- 1 What is the relationship between a place's latitude and the shadow cast by the stick?
- 2 What happens to the length of the day as latitude increases towards the south?
- 3 How would the shadow lengths be different during winter?

4.6 LEARNING CHECK

- 1 **Define** season.
- 2 **List** the seasons that occur where you live.
- 3 **List** the four seasons, in order, experienced by people in southern Australia.
- 4 **Describe** two ways the tilt of Earth leads to seasons.
- 5 **Draw** a labelled diagram to show Earth's orientation when it is:
 - a summer in the southern hemisphere.
 - b autumn in the southern hemisphere.
- 6 **Describe** what the world would be like if, like the planet Uranus, the axis always pointed towards the Sun.



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ following a planned procedure controlling appropriate variables
- ▶ proposing inferences based on observations
- ▶ using a physical model of the Sun and Earth to explain the cause of seasons.

EARTH'S TILT AND ILLUMINATION

AIM

To use a physical model to explore how the angle of light illumination affects surface heating

MATERIALS AND EQUIPMENT

- large ball
- torch
- cardboard tube about 10 cm long
- marker pens
- 30 cm ruler

PROCEDURE

- 1 Mark a point on the top of the ball with a marker pen. Label this point 'equator'.
- 2 Mark a point 3 cm from the top of the ball. Label this point 'high latitude'.
- 3 Hold the tube 5 cm above the 'equator'. Shine light from the torch down the tube. Draw a line around the area lit by the torch on the ball.
- 4 Repeat step 3, holding the tube above the 'high latitude' point. Remember to keep the tube vertical and the same distance from the point as you did for step 3.
- 5 Calculate the area of the circles you have drawn and record them in your results.

RESULTS

Compare the area lit up on the ball for the 'equator' and at 'high latitude' points.

ANALYSIS

- 1 Were the areas the same size?
- 2 If light carries energy that turns into heat, which area will warm faster? Why do you think so?
- 3 If Earth's axis was vertical, would the hemispheres show different heating rates? Explain your answer.
- 4 Why does a tilt mean one hemisphere warms more?

CONCLUSION

How does the tilt of Earth affect heating of the hemispheres?

4.8 Phases of the Moon

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

✓ identify and explain the phases of the Moon.



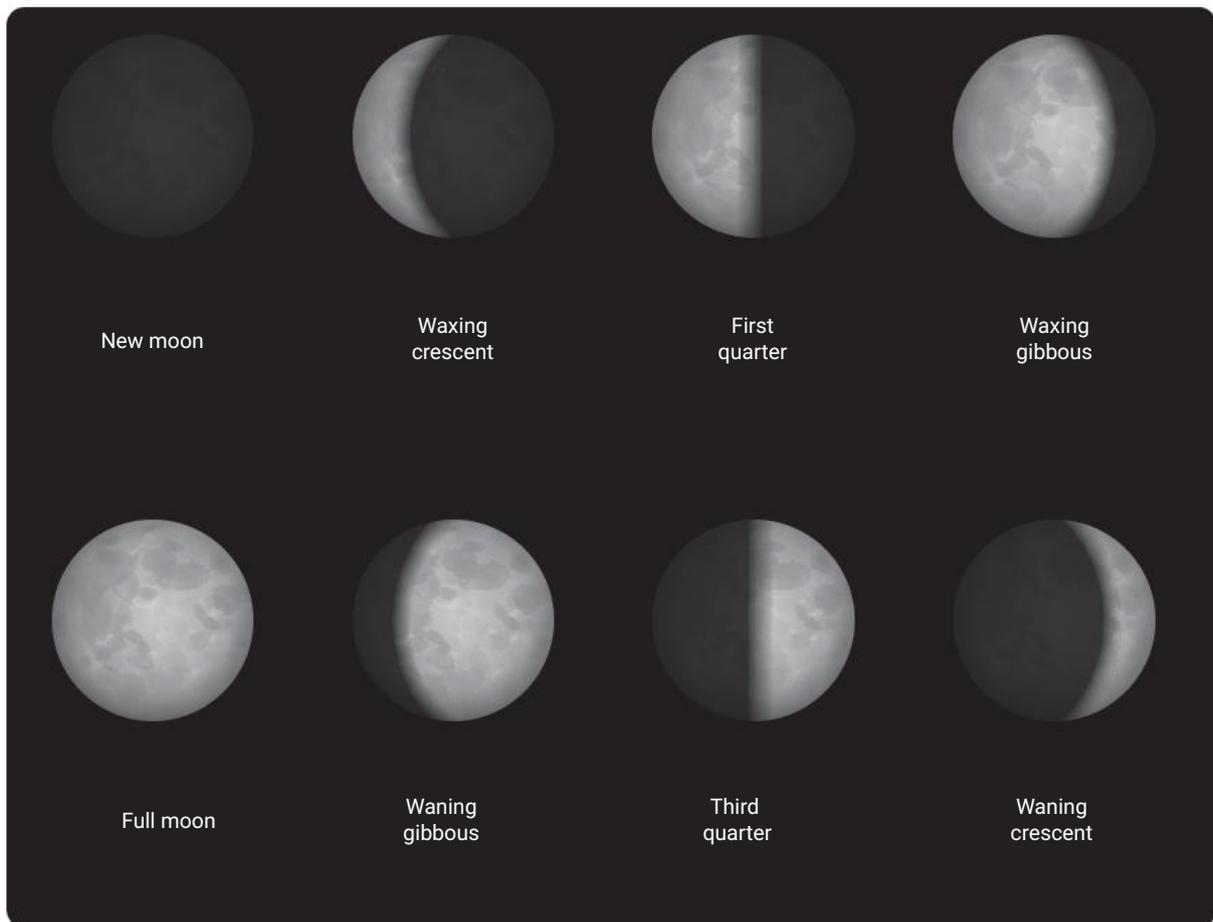
Interactive resource
Match: Phases of the Moon

GET THINKING

Why does the Moon shine more brightly on some nights than on others? What causes the amount of moonlight to change? Over the course of a month, take photos of the Moon on different nights. Describe all the changes you see as the Moon changes its appearance.

The Moon's appearance changes over a month

We see the Moon because of reflected light. When light falls on the Moon's surface from the Sun, it is reflected towards Earth, and we see a bright surface. Earth also reflects light. Some of the reflected light is reflected again from the dark areas of the Moon not lit by the Sun, so we see a dim outline of these areas. As the Moon orbits Earth, we see different amounts of the Moon's surface that is reflecting light from the Sun (Figure 4.8.1). The amount of the Moon shining with reflected light waxes (grows) and then wanes (shrinks). This is because the angle at which we view the Moon changes.



Peter Hermes Furian/Shutterstock.com

▲ FIGURE 4.8.1 How the phases of the Moon appear

The cycle of phases

The phases of the Moon are the different appearances of the Moon. It takes 29.5 days to move through the eight phases. This is slightly different from the time it takes the Moon to orbit Earth (27.3 days) because Earth has also moved in this time, and it takes 2.2 days for the Moon to reach the position for the original phase.

The phases are usually ordered beginning with the new moon (Figure 4.8.2). A **new moon** occurs when the Moon is between Earth and the Sun. When this happens, the surface of the Moon we see does not receive light from the Sun and it appears as a dark disc.

The bright area that we can see increases as the Moon is **waxing**. A **crescent** phase occurs when less than half of the side of the Moon facing Earth is lit. The bright area is thicker in the middle and tapering to points.

When we see half the Moon lit by the Sun, the Moon is in its first quarter. The quarter refers to it being a quarter way through its phases – we can actually see half the lit face.

When more than half the Moon that we see is bright, we call the phase a **gibbous** moon. The amount of the bright side we see continues to grow until the whole side of the Moon reflecting light from the Sun is visible. This is a **full moon**.

After reaching the full moon phase, the shadowed area of the Moon starts to grow, and the bright area shrinks. The bright area is said to be **waning**. Initially, this is a waning gibbous moon, with more than half of the Moon that we see lit. When the Moon has half of its lit surface visible from Earth, it has reached its third quarter. Because less than half of the side of the Moon that we see is lit, another crescent moon occurs. This is the waning crescent moon.

new moon

a phase of the Moon when the part of the Moon facing Earth is in darkness

waxing

when the area of the bright surface of the Moon visible from Earth is increasing

crescent

a phase of the Moon when only a small arc-shaped section of the Moon is visible from Earth

gibbous

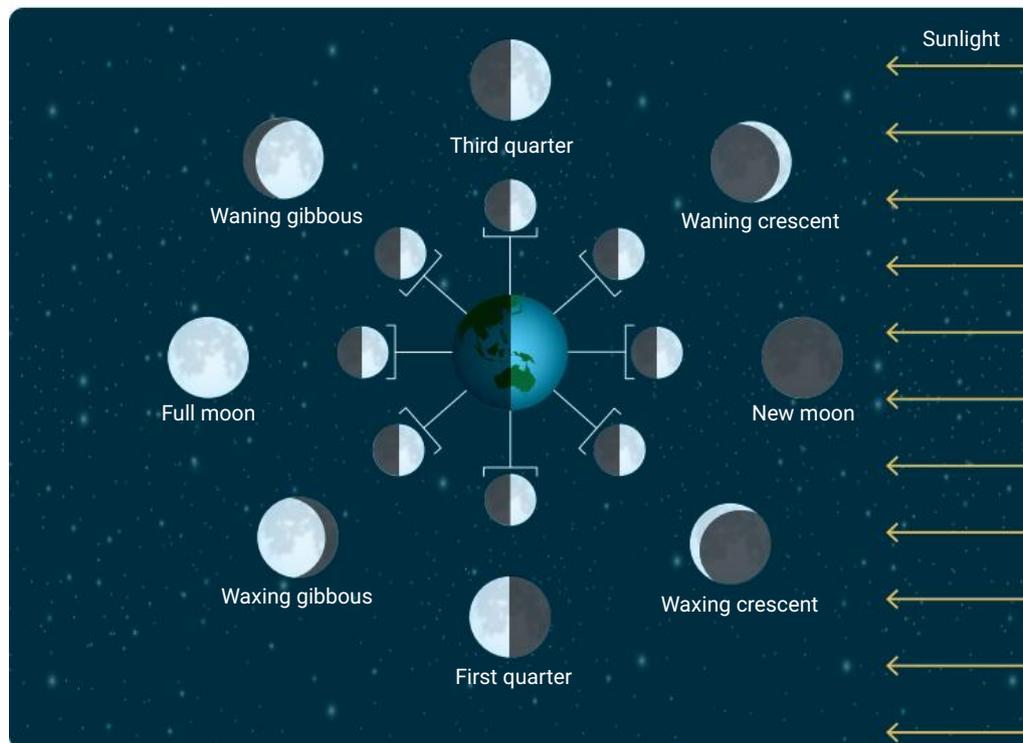
a phase of the Moon when more than half of the illuminated face of the Moon is visible from Earth

full moon

a phase of the Moon when the whole lit face of the Moon is visible from Earth

waning

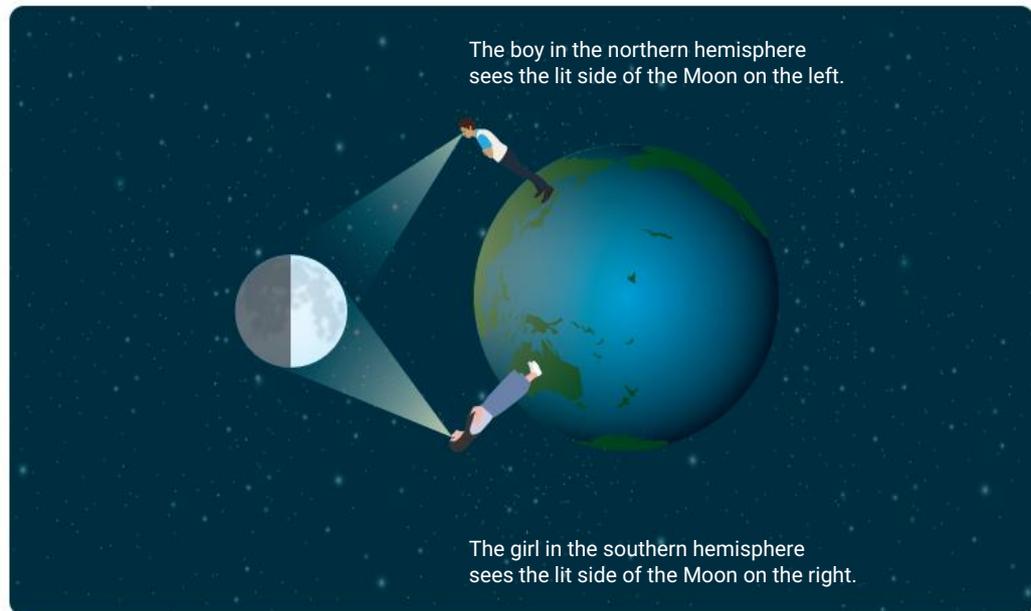
when the area of the bright surface of the Moon visible from Earth is decreasing



▲ FIGURE 4.8.2 The phases of the Moon. The Moon is lit from the same direction, and we always see the same face of the Moon, but we see different amounts of its illuminated surface.

The upside-down Moon

The same phases of the Moon are seen in both the northern and the southern hemispheres, but in the north, things appear upside down and back to front compared with what we see in the south (Figure 4.8.3). In the southern hemisphere, the Moon increases in brightness from the left. In the northern hemisphere, the brightness increases from the right. This is due to the direction from which we are viewing the Moon – people in different hemispheres see the Moon from opposite sides. If you look at the same thing, such as the Moon, from opposite sides, what is on the left from one side will be on the right from the other side.



▲ FIGURE 4.8.3 What you see depends on where you are looking from.

4.8 LEARNING CHECK

- 1 **State** how long it takes the Moon to revolve once around Earth.
- 2 **Compare** the meanings of the words 'waxing' and 'waning'.
- 3 **List** the eight phases of the Moon, in order, starting with a new moon.
- 4 **Draw** a diagram to show the difference between a crescent and a gibbous phase of the Moon.
- 5 **Describe** the appearance of a crescent moon.
- 6 **Describe** how a waxing gibbous moon is different from a waning crescent moon.
- 7 **Create** a labelled diagram to explain the appearance of the Moon at the first quarter.



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ using a physical model of the Sun, Earth and Moon to explain the cause of Moon phases
- ▶ assessing the reliability of gathered data by comparing it with observations and data from other sources.

MODELLING PHASES OF THE MOON

AIM

To model how the phases of the Moon are created by the position of the Moon relative to Earth and the Sun

MATERIALS AND EQUIPMENT

- chair in the centre of the room with 2 m of clear space around it
- large ball with one half light and the other dark

PROCEDURE

This modelling activity requires two people: an observer and a Moon carrier.

- 1 The observer sits in the chair.
- 2 The Moon carrier holds the ball in front of the observer at head height. Make sure the light half of the ball is facing the front of the room and is about 1.5 m from the observer.
- 3 The observer draws what they see, labelling the dark and light parts of the ball.
- 4 Use Figure 4.8.2 (p. 149) as a guide to move the ball to the other seven moon phase positions, keeping the ball's light half always pointing towards the front of the room.
- 5 Have the observer turn towards the ball at each position and draw the appearance of the ball.

RESULTS

Create eight labelled drawings of the ball showing the dark and light areas that you see. Name each drawing with the phase of the Moon (new moon, waxing crescent etc.) as shown in Figure 4.8.2.

ANALYSIS

- 1 Do your drawings resemble the phases of the Moon?
- 2 How well does the model help you to understand how the phases of the Moon are created?
- 3 Compare your drawings with the figures in Module 4.8. What similarities and differences can you identify?

CONCLUSION

Describe how a model helps our understanding of the phases of the Moon.

4.10 Eclipses

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe solar and lunar eclipses and explain why they occur
- ✓ explain why total and partial eclipses occur
- ✓ model how eclipses are caused.



Video activity
What are eclipses?

Extra science investigation
Modelling eclipses

eclipse

when light from the Sun is blocked by another object

GET THINKING

Look carefully at the images in this module. Use a torch (for the Sun), a tennis ball (for Earth) and a ping pong ball (for the Moon) to model the arrangements for each type of eclipse. Make a summary of what you think is happening.

Why eclipses occur

An **eclipse** occurs when light from the Sun is blocked by another object, which casts a shadow. If the Moon casts a shadow on Earth, it has blocked light from the Sun. When Earth casts a shadow on the Moon, the brightness of the Moon dims because there is less light from the Sun available to be reflected.



Alexey Stlop/Shutterstock.com

▲ FIGURE 4.10.1 This time-lapse photograph shows an eclipse of the Moon.

lunar eclipse

when Earth blocks the Sun's light from reaching the Moon

umbra

the innermost, darkest part of a shadow where the light is completely blocked by an object

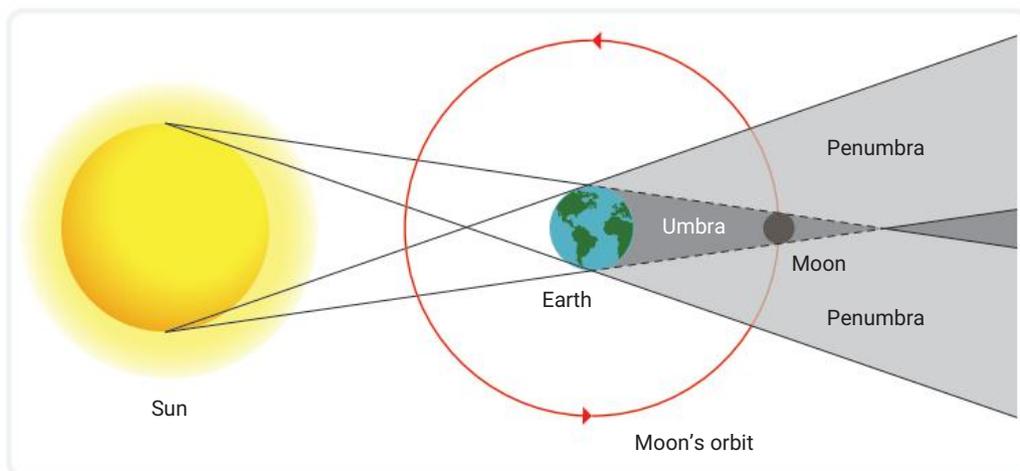
total lunar eclipse

when the Moon is in the umbra of Earth's shadow and none of the Moon is easily visible

Lunar eclipses

A **lunar eclipse** occurs when the Moon enters the shadow cast by Earth (Figure 4.10.2). This happens when Earth is directly between the Sun and Moon. Therefore, a lunar eclipse occurs when the Moon is full.

As the Moon enters Earth's shadow, its surface darkens. The area where light from the Sun is completely blocked is called the **umbra**. When the Moon is in the umbra, a **total lunar eclipse** occurs. During a total lunar eclipse, the Moon may become slightly red (Figure 4.10.3). This is because the light that reaches the Moon has passed through Earth's atmosphere. In the atmosphere, blue light is scattered so mainly red light reaches, and is reflected from, the Moon.



▲ FIGURE 4.10.2 A lunar eclipse is caused by Earth moving between the Moon and the Sun.

Surrounding the umbra is an area where only part of the Sun's light is blocked by Earth. This is called the **penumbra**. When the Moon is partly in the umbra and partly in the penumbra, a **partial lunar eclipse** occurs (Figure 4.10.4). This is seen as part of the Moon being covered by a shadow.

penumbra

the outermost part of a shadow where only some of the light is blocked by an object

partial lunar eclipse

when part of the light from the Sun reaching the Moon is blocked by Earth; only a portion of the Moon is visible from Earth

ChameleonsEye/Shutterstock.com



▲ FIGURE 4.10.3 A total lunar eclipse

underworld/Shutterstock.com



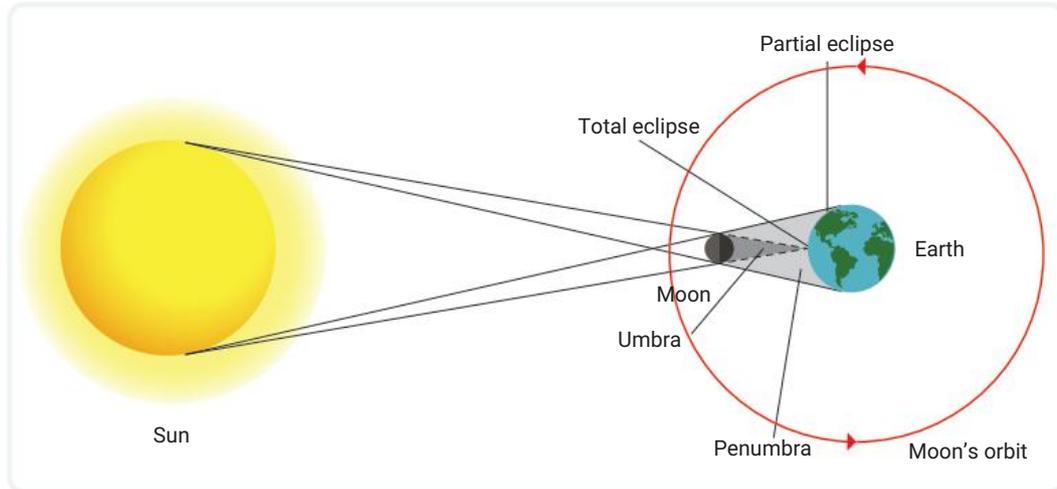
▲ FIGURE 4.10.4 A partial lunar eclipse

Solar eclipses

solar eclipse

when the Moon passes between Earth and the Sun, blocking the view of the Sun from Earth

A **solar eclipse** occurs when the Moon is between the Sun and Earth (Figure 4.10.5). Therefore, they occur during the new moon phase. As in a lunar eclipse, an umbra and penumbra occur in solar eclipses. When the Moon is between the Sun and Earth, it casts a shadow on Earth's surface, creating an umbra and a penumbra, as seen in Figure 4.10.5.



▲ FIGURE 4.10.5 A solar eclipse is caused by the Moon moving between Earth and the Sun.

Looking from Earth in the umbra, the face of the Moon completely covers the Sun, causing a **total solar eclipse**. Only the bright outer atmosphere of the Sun, the **corona**, is visible during a total solar eclipse (Figure 4.10.6). Total solar eclipses are rare though because the area of the umbra is very small on Earth's surface.

total solar eclipse

when Earth is in the umbra of the Moon's shadow; none of the Sun is visible from Earth

corona

the bright outer atmosphere of the Sun

partial solar eclipse

when the Moon's shadow stops a portion of the Sun's rays reaching Earth; only a portion of the Sun is visible from Earth

A **partial solar eclipse** is where only part of the Sun is blocked by the Moon (Figure 4.10.7). On Earth, a partial eclipse is seen by a person standing in the penumbra. The part of the Sun in the shadow is dark and the rest is bright.



▲ FIGURE 4.10.6 A total solar eclipse



▲ FIGURE 4.10.7 A partial solar eclipse

When do eclipses occur?

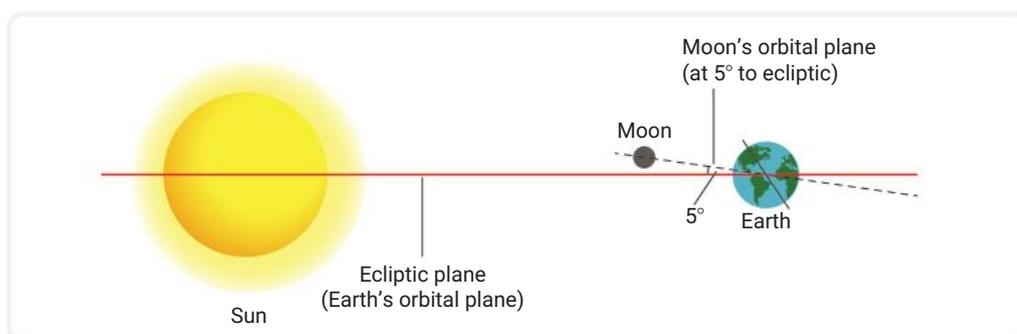
The probability of an eclipse occurring depends on the:

- size of the object blocking the light
- distance between the Sun, Earth and the Moon
- inclination of orbits.

Eclipses only occur when the Sun, Earth and the Moon are in alignment. The Moon's orbit is at a 5° angle to a line between the Sun and Earth (Figure 4.10.8). Therefore, the Moon will not be in line with the Sun and Earth at every new moon or full moon. When this happens, Earth's shadow doesn't fall on the Moon, or the Moon's shadow on Earth.

Solar eclipses occur 2–5 times a year, and there are two total solar eclipses every 3 years. Each solar eclipse only lasts a few minutes before the shadow has moved. They are only seen from a small part of Earth several hundred kilometres across because the shadow from the Moon only covers a small area. Sometimes this area is in the ocean or an uninhabited location, making solar eclipses appear rarer than they actually are.

There are between zero and three lunar eclipses every year. Each one lasts for a few hours and can be seen from anywhere on Earth.



▲ FIGURE 4.10.8 The Moon orbits at an angle of 5° to the orbital plane of Earth around the Sun.

4.10 LEARNING CHECK

- 1 **Define** eclipse.
- 2 **Explain** how a solar eclipse is different from a lunar eclipse.
- 3 Make a labelled drawing of the alignment of the Sun, Earth and the Moon needed to create a:
 - a solar eclipse.
 - b lunar eclipse.
- 4 **Explain** why both full and partial eclipses occur.
- 5 Use a light and two different-sized balls to **model** how a total and a partial eclipse are created.

4.11 Tides

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe the nature of high, low, spring and neap tides
- ✓ explain why the height of tides changes daily and over a lunar cycle.



Video activity
The Moon and spring tides

Extra science investigation
The effect of the Moon on tides

GET THINKING

Have you ever been to the beach and noticed that the distance water moves up the beach changes during the day? The maximum distance the water travels up the beach, and when it happens, changes from day to day. Why does this happen? Write down your theory.

What are tides?

tide
the regular rise and fall of the surface of the ocean

high tide
when the tide reaches its maximum level

low tide
when the tide reaches its lowest level

tidal range
the difference between the height of high and low tide

Tides are the regular rise and fall of the surface of the ocean. At the beach and along the coast, the average height of the sea, and how far it reaches up the beach, changes each day. The highest level of the ocean is called **high tide** and the lowest level is called **low tide**. The difference in height of high and low tides is called the **tidal range**.

Tides do not occur at the same time every day and they vary in range. Most places have two high tides and two low tides each day. However, in some places, such as the Gulf of Carpentaria, the Gulf of Thailand, the Persian Gulf and the Gulf of Mexico, there are only one high tide and one low tide in a day.

blueeyes/Shutterstock.com



▲ **FIGURE 4.11.1** Low tide. How do animals adapt to changing sea levels?



▲ **FIGURE 4.11.2** The Bay of Fundy in Canada has the greatest tidal range in the world. How high does the water rise in the image?

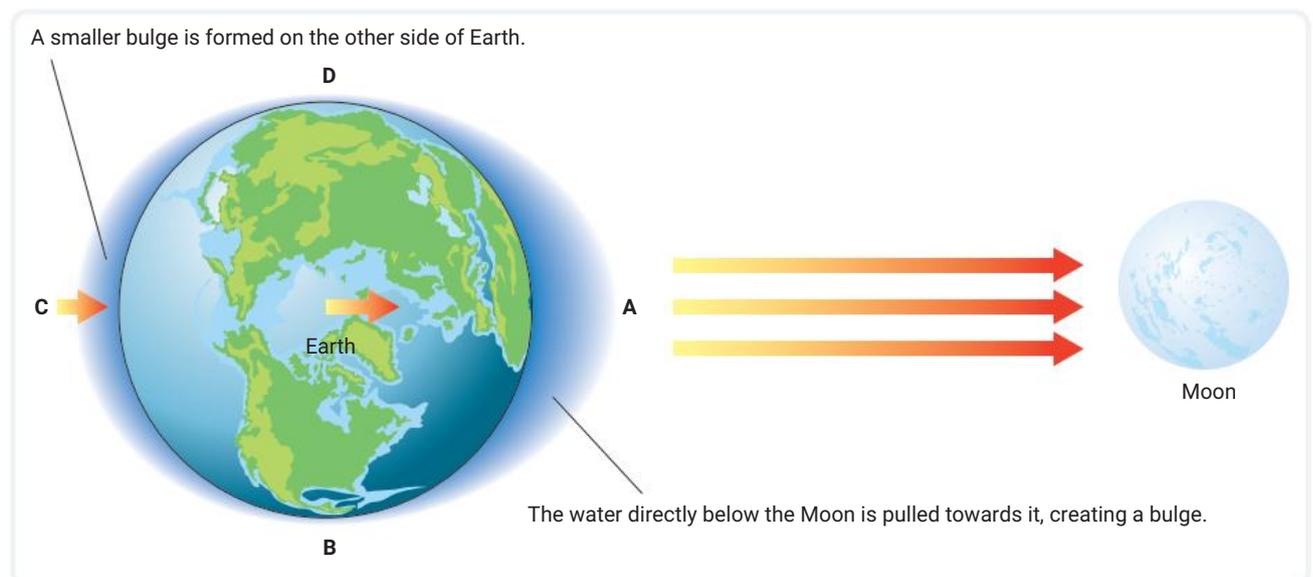
Rob Crandall/Shutterstock.com

The cause of tides

Tides are caused by gravity. The ocean is attracted by gravitational forces to the Moon and the Sun (Figure 4.11.3). The Moon has a greater effect on the tides because it is much closer to Earth than the Sun is. The size and direction of the forces vary around Earth. Ocean water flows towards the area of the ocean where the gravitational pull is greatest. The gravitational pull creates two slight bulges on opposite sides of Earth – one closest to the Moon (A) and the other on the opposite side of Earth (C) (Figure 4.11.3). At right angles to the bulges (B and D), the water depth is lower because of the lack of gravitational force in that direction.

Tides are created as Earth rotates under the bulges. As Earth rotates, a bulge approaches a coast, and the water rises to create a high tide. As the bulge moves away, the water falls to create a low tide.

Tides do not occur at the same time every day. Earth rotates faster than the Moon orbits Earth. As Earth spins in the same direction the Moon orbits, it takes an extra 50 minutes for Earth to return to the same place relative to the Moon. This means that the gravitation pull from the Moon causes high and low tides at slightly different times every day.



▲ FIGURE 4.11.3 The cause of tides. As Earth rotates, coastal places experience high tide (A), then low tide (B), then a lower high tide (C), and then low tide (D).

Spring and neap tides

spring tide

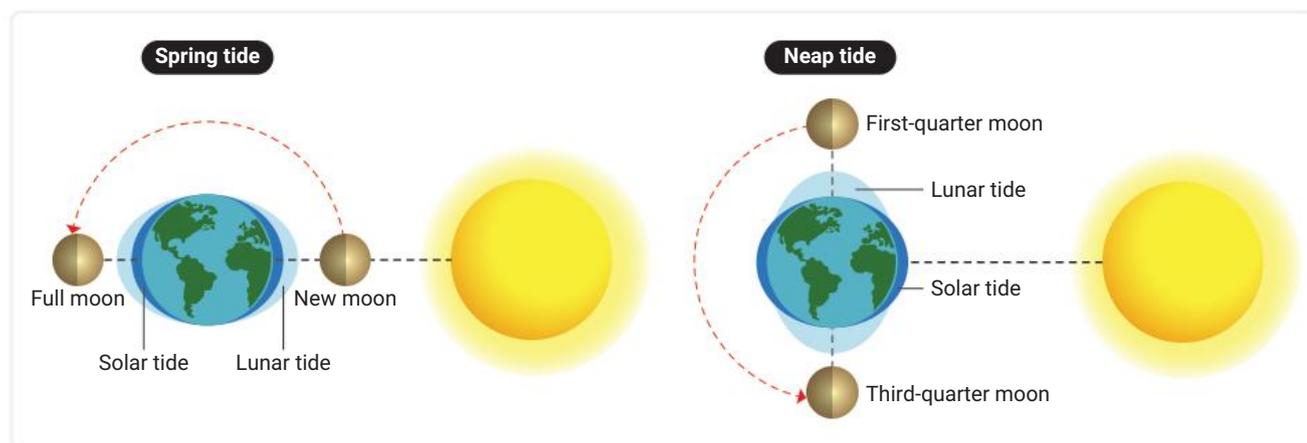
a high tide caused by the alignment of the Sun, Earth and the Moon

neap tide

a tide where the difference between high tide and low tide is small

When the Moon is in line with the Sun and Earth, the gravitational attraction from both the Sun and Moon is acting in the same direction. This makes the tides higher than at other times. These high tides are referred to as **spring tides** (Figure 4.11.4) and occur during the new moon and full moon phases.

When the Moon is at a right angle (90°) to the line between the Sun and Earth, the Sun's gravitational attraction reduces the effect of the Moon's gravity and, therefore, the tide height. This is called a **neap tide** and occurs a week after a new or full moon. During a neap tide, there is only a small difference between high and low tides.



▲ FIGURE 4.11.4 Spring and neap tides

4.11 LEARNING CHECK

- 1 **Define** tide.
- 2 **Identify** how many high tides usually occur in 24 hours on the coast closest to where you live.
- 3 **Describe** how the Moon affects tides.
- 4 Which phases of the Moon occur when spring tides happen?
- 5 **Describe** two things that affect the size of tides.
- 6 **Explain** why the Sun has less effect on Earth's tides than the Moon does.
- 7 **Explain** why a neap tide is smaller than a spring tide.
- 8 **Locate** a tide chart for an area near where you live. How many minutes, on average, does the time of high tide change from day to day?

4.12

Knowledge of Moon phases and tides

**IN THIS MODULE
YOU WILL:**

- ✓ explore Aboriginal and Torres Strait Islander Peoples' knowledge of the phases of the Moon
- ✓ examine Aboriginal and Torres Strait Islander Peoples' understanding of the relationship between the Moon and tides.

Phases of the Moon

For many thousands of years, Aboriginal and Torres Strait Islander Peoples have observed the night sky and built a wealth of astronomical knowledge. Their records of the repeating patterns and relationships between celestial bodies are preserved in cultural narratives (stories, songs and performances that are used to pass on important cultural knowledge, values and beliefs), petroglyphs (images engraved into rock), stone arrangements and paintings.



Joe Sambono

▲ **FIGURE 4.12.1** For many Aboriginal and Torres Strait Islander Peoples, the words for 'moon' and 'month' are similar; Mithaka Country, far western Queensland.

Timekeeping

Prior to colonisation, timekeeping systems of many Aboriginal and Torres Strait Islander Peoples were based on cyclical patterns of the Moon. For example, the Ngarrindjeri Peoples of the Southern Coorong district of South Australia recorded the age of children less than one year old by the number of full moons that had passed since their birth. The Takayna Peoples of north-west Tasmania applied lunar phases to the timing of gatherings; for example, the number of dark days after the Moon had disappeared.

For many Aboriginal and Torres Strait Islander Peoples, the knowledge that the Moon takes a month to complete a cycle of the Earth is shown by the use of the same, or a closely linked, word for both 'moon' and 'month'. For example, the Meriam Mir Peoples of the eastern Torres Strait use the word *meb*, which means both moon and month. They also have names for the different lunar phases: new moon is *aketi meb*, first quarter moon is *meb degemli*, a waxing or waning moon is *eip meb* and a full moon is *giz meb*.

Evidence of Aboriginal Peoples' understanding of the phases of the Moon is also found in petroglyphs. For example, at a site within what is now the Ku-ring-gai Chase National Park (north of Sydney) the Guringai Peoples of the Sydney region communicated their observations and understanding of the phases of the Moon in a series of eight rock engravings portraying the lunar calendar.

The Moon and the Sun

Aboriginal and Torres Strait Islander Peoples have long identified relationships between the Moon and the Sun. For example, a cultural narrative of the Palawa Peoples of Tasmania tells of a Sun Man and Moon Woman who rose into the sky together on the first day. The Sun Man moved faster through the sky than the Moon Woman. To encourage her to catch up, he illuminated more of her each night until she was fully lit.

☆ ACTIVITY 1

- 1 **Discuss** the advantages of having timekeeping systems for shorter and longer periods.
- 2 After reading about the cultural narrative above:
 - a **relate** the events in the narrative about the Sun Man and the Moon Woman to the phases of the Moon.
 - b **describe** what information it conveys about the relative position of the Moon and Sun at different times.
 - c **explain** the contemporary scientific understanding this demonstrates.

Relationship between the Moon and tides

Knowledge of relationships between the Moon and tides has been gained by Aboriginal and Torres Strait Islander Peoples through continuous observation of the position and phases of the Moon and ocean tides. This understanding has long enabled predictions about timing and height of tides, informing many Aboriginal and Torres Strait Islander Peoples' practices and technologies.

For example, some Aboriginal and Torres Strait Islander Peoples constructed and used fish traps. These traps were generally constructed from stone and positioned in an inter-tidal area. To be effective, their construction requires a detailed knowledge of variations in ocean currents, tide heights and times.



▲ FIGURE 4.12.2 Stone fish traps rely on the lunar cycle: (a) fish trap on Gangalidda Country, the Gulf of Carpentaria, Queensland; (b) Toorbul Point fish trap on Ningy Ningy Country, Brisbane.

The Narungga Peoples of the Yorke Peninsula region of South Australia constructed fish traps perpendicular to the shoreline and the direction of tides and currents. The Burgiyana fish trap at Point Pearce is constructed within the minimum and maximum tidal range. At high tide, the walls of the trap are submerged and water flows in. As the tide recedes, water flows out of the structure, leaving fish trapped, which can then be harvested.

The Dampier Peninsula region of Western Australia experiences one of the largest tidal variations in Australia, up to 11 metres. The Bardi Peoples of this region have long used knowledge of lunar phases and the connection with tides to time safe travel between islands, during neap tides. For thousands of years, the Bardi Peoples have also taken advantage of low tides to access large intertidal reefs, rock shelves and mudflats, which provide sources of food and cultural and economic resources, such as fish, and pearl and trochus shells.



Joe Sambono

▲ FIGURE 4.12.3 A trochus shell

- 1 **Explain** the relationship between use of fish traps and tides.
- 2 **Relate** the maximum and minimum tidal range to specific phases of the Moon.
- 3 **Explain** the difference between a neap tide and a low tide.
- 4 **Suggest** why the Bardi Peoples might specifically choose to travel at neap tides rather than just low tides.

☆ **ACTIVITY 2**

4.13 Australian advances in astronomy

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ explain how observations are used by scientists to increase knowledge and understanding of the universe
- ✓ describe a recent Australian advancement in science that has increased knowledge of the universe.



Video activity
SKA

Discoveries from light and other radiation

Astronomers get information from stars and other objects in space to learn about the universe. They use visible light, radio waves and microwaves from stars and galaxies.

Australians have a long history of extracting information from the night sky. Aboriginal and Torres Strait Islander Peoples have observed the night sky for many thousands of years and applied their knowledge of the stars to do things such as navigate, hunt and share cultural information.

Astronomers use observations and data to test theories about space and the universe. For example, Professor Brian Schmidt from the Australian National Observatory studied exploding stars, or supernovae, and found evidence that the universe is expanding at an increasing rate. In 2011, he won the Nobel Prize in Physics with Saul Perlmutter and Adam Riess for his discoveries.

Radioastronomy

Many objects in space emit radio waves as well as visible light. Studying the sky using radio waves is called radioastronomy. Some of the discoveries made by Australian scientists using radioastronomy include:

- linking the **sunspots** and **solar flares** on our Sun with the emission of radio waves
- identifying the first quasar, in 1962. Quasars are very **luminous**, distant objects in space. Studying them helps scientists better understand the size of the universe
- finding **pulsars**. Pulsars are rapidly spinning stars that emit pulses of radio waves and other forms of energy. Two thirds of the known pulsars have been identified by astronomers at the Murriyang radio telescope near Parkes, New South Wales (Figure 4.13.1).



▲ FIGURE 4.13.1 The Murriyang radio telescope near Parkes, New South Wales.

sunspots

dark spots or patches that appear on the surface of the Sun

solar flares

eruptions of energy from the surface of the Sun that can cause radio and magnetic effects on Earth

luminous

bright, giving off light

pulsar

a rapidly spinning star that emits pulses of energy

The Square Kilometre Arrays

Australian astronomers and engineers are currently working with scientists from 16 other countries to build two of the largest radio telescope arrays in the world. The Square Kilometre Arrays (SKA) consist of hundreds of dish antennas concentrated in small areas. One array, called SKA-Mid, is based in South Africa and uses 197 dish antennas to detect mid-frequency radio waves. The second array, named SKA-low, is being built in Western Australia (Figure 4.13.2) and will detect low-frequency radio waves.



AAP Image/Supplied by Ogilvy/PR Handout Image

▲ FIGURE 4.13.2 An artist's impression of the Square Kilometre Array (SKA-low) in Western Australia

DATA SCIENCE



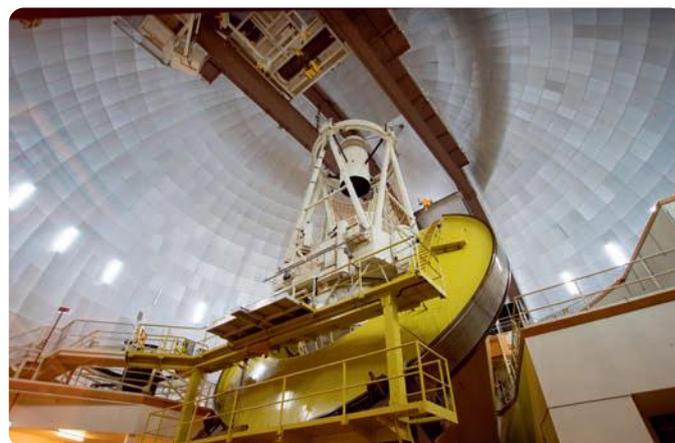
Learn more about big data in **Module 2.5**.

The amount of information the SKA will generate is amazing; around 100 trillion bits of data will be gathered every second! To make sense of that information, the data will be processed by the Pawsey Supercomputing Research Centre in Perth. An early part of the array, the Australian SKA Pathfinder Telescope (ASKAP), mapped the position of 300 million galaxies in only 300 hours. One hundred million of the galaxies had not been observed before.

Optical astronomy

Visible light can tell astronomers a lot about a star or galaxy. For example, scientists can analyse light to identify the size and temperature of a star, as well as how fast it is moving. The Anglo-Australian telescope (AAT) at Siding Springs, near Coonabarabran, New South Wales, is the largest optical telescope in Australia (Figure 4.13.3).

The AAT has made a number of important discoveries. In 1987, astronomers observed through it the explosion of an enormous star, more than 10 000 times more massive than our Sun. Named Supernova 1987A, it was the brightest supernova seen since the invention of the telescope. It was also the first supernova that astronomers were able to observe in great detail. Observations of the supernova provided astronomers with important knowledge about how some stars come to an end.



Ray Pemberton/Shutterstock.com

▲ FIGURE 4.13.3 The Anglo-Australian Telescope is Australia's largest optical telescope

4.13 LEARNING CHECK

- 1 **List** some of the star properties astronomers can infer from studying starlight.
- 2 **Describe** two discoveries that Australian astronomers have made.
- 3 **Explain** how the discovery of an object such as a supernova changes our understanding of the universe.

4 REVIEW

REMEMBERING

- 1 **Recall** the time it takes for:
 - a Earth to orbit the Sun.
 - b the Moon to orbit Earth.
 - c the Moon to rotate once.
 - d the rotational period of Earth.
- 2 **State** the angle of tilt of Earth's axis.
- 3 **Describe** the difference between a planet's rotation and its revolution.
- 4 **Name** the season normally associated with the weather shown in each image. For each season, sketch the position of the Sun and Earth at this time of year.

a



b



c



d



- 5 **Outline** the cause of tides.
- 6 **List** the phases of the Moon shown below in order, starting with the new moon.



UNDERSTANDING

- 7 **Explain** the cause of day and night.
- 8 **Explain** the cause of the eclipse shown in the image.



- 9 **Summarise** the causes of the warm conditions that occur during summer.
- 10 **Distinguish** between the causes of spring and neap tides.
- 11 **Explain** why the Moon appears upside down in the northern hemisphere compared with what we see in Australia.
- 12 **Describe** examples of Aboriginal and Torres Strait Islander Peoples' application of their understandings of phases of the Moon and tides.
- 13 **Explain** how astronomers use radio waves to learn more about the universe.

APPLYING

- 14 Olivia was modelling how the angle of a beam of light on a surface warmed the surface. The results from Olivia's experiment are shown in the table.

Angle of light to the surface (degrees)	Area of light (cm ²)	Change in temperature after 2 minutes (°C)
90	3.5	4.3
60	6.2	1.9
30	9.1	1.3

- a **Describe** the trends shown in the data.
- b **Explain** how the results of the modelling can be used to explain the cause of the seasons.
- 15 **Draw** a labelled diagram to show how increasing the distance of Earth from the Sun increases the length of a year if Earth continues in orbit at the same speed.
- 16 **Draw** a labelled diagram to show how a lunar eclipse occurs. On your diagram, show the positions of the Moon where total and partial lunar eclipses would be seen from Earth.
- 17 Finn, a student in Perth, was speaking with Annika, a student in Vancouver, Canada, about the *Apollo 11* Moon landing. Finn said that the landing site was on the eastern side of the Moon, but Annika said they had a picture showing the landing site on the western side of the Moon. **Explain** why they can both be correct.

ANALYSING

- 18 **Compare** the cause of a high tide with the cause of a spring tide.
- 19 **Compare** the seasons in southern Australia with seasons in tropical northern areas of Australia.
- 20 What would happen to the length of a lunar cycle if:
 - a the Moon moved further away from Earth and slowed down?
 - b the speed of Earth's rotation increased?
 - c Earth's period of revolution was slower?
- 21 **Compare** a heliocentric model of our solar system with a geocentric model. What are the most important differences between the models?

EVALUATING

- 22 **Assess** how the seasons would change if Earth's axial tilt increased.
- 23 In modules 4.2, 4.7 and 4.9, you used models to explore processes such as day and night, phases of the Moon and the effect of axial tilt on the intensity of light on hemispheres. **Justify** the use of models in helping students understand the processes affecting Earth and the Moon.
- 24 **Evaluate** the effect that having two moons, rather than one, would have on Earth's tides. Give reasons for your judgement.

CREATING

- 25 **Construct** a concept map showing the relationship between Earth, the Sun and the Moon. Include rotations, tilt, orbital planes, revolutions, phases, tides, eclipses and seasons in your concept map.
- 26 A flat, two-dimensional map of the Moon circling Earth would suggest that there should be two eclipses each month. **Make** a model to show how the inclination of the Moon's orbital plane means that a shadow is not always cast on Earth or the Moon during a lunar month.

SCIENCE IN DEPTH STUDY

#4

A new planet, nicknamed Novaterra, has been discovered orbiting a star like our Sun. You have been asked to put together a presentation on what that planet might be like.

1 Connect what you've learned

In this chapter, you've learned about the origin of seasons, phases of the Moon, tides and eclipses. Make a labelled drawing that summarises the origins and causes of these things.

2 Check your thinking

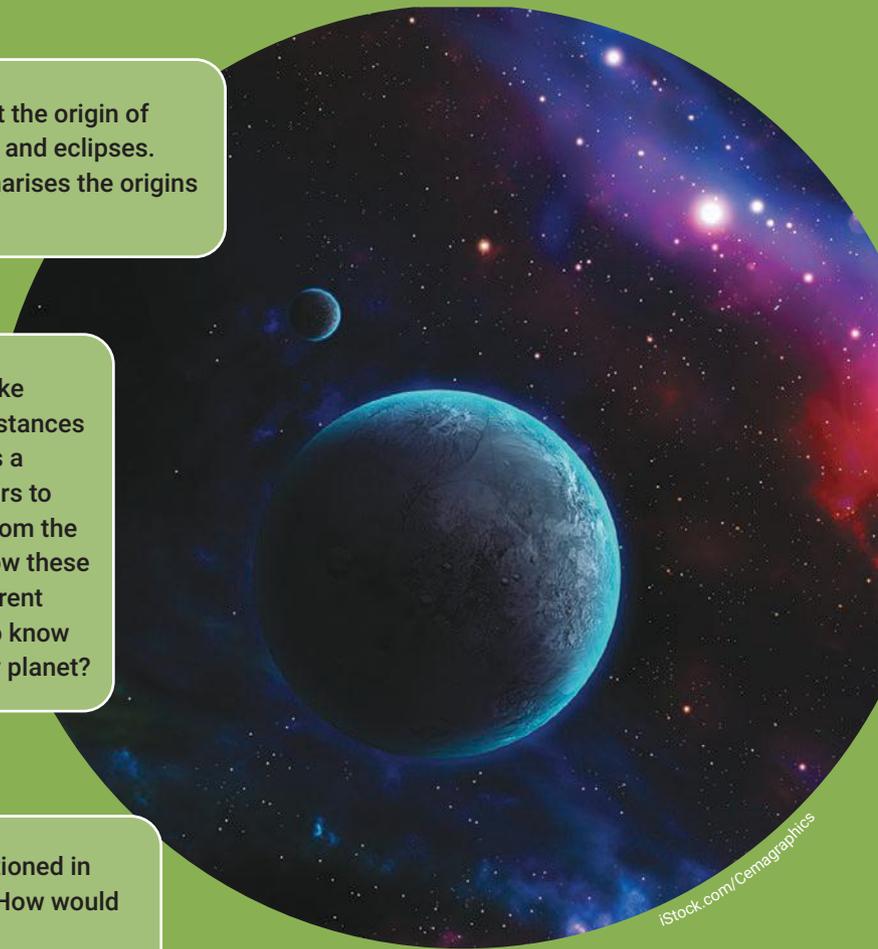
The new planet has an ocean and continents like Earth. It has two moons orbiting at different distances on opposite sides of the planet. The planet has a tilt slightly larger than Earth's and takes 30 hours to complete one spin. It is slightly further away from the star than Earth is from the Sun. Think about how these differences would make life on Novaterra different from life on Earth. Are there things you need to know to predict eclipses or Moon phases on the new planet?

3 Get into action

For each property of the new planet mentioned in step 2, predict the effects it would have. How would the new planet be different from Earth?

4 Communicate

Use your knowledge and understanding to create a presentation to explain how Novaterra compares with Earth.



▲ Exoplanets are planets that orbit stars other than our Sun.

istock.com/Cemagraphics

FORCES

SYLLABUS OUTCOMES

A STUDENT:

- ▶ describes the effects of forces in everyday contexts **SC4-FOR-01**
- ▶ identifies questions and makes predictions to guide scientific investigations **SC4-WS-02**
- ▶ uses a variety of ways to process and represent data **SC4-WS-05**
- ▶ uses data to identify trends, patterns and relationships, and draw conclusions **SC4-WS-06**
- ▶ identifies problem-solving strategies and proposes solutions **SC4-WS-07**

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THE CHAPTER RELATED TO THIS FOCUS AREA IS:

- ▶ **CHAPTER 5 – FORCES**



Rostislav Glimsky/Shutterstock.com

5

Forces

5.1 What is a force? (p. 170)

A force is a push, pull, twist or squeeze applied by an object to another object.

5.2 Measuring forces (p. 174)

We measure forces using a device such as a spring balance. The unit of force is the newton.

5.4 Indirect forces (p. 178)

Some objects can exert an indirect force at a distance without any contact or connection.

5.3 Direct forces (p. 176)

Direct forces are exerted on objects by other objects that are touching them or connected to them.

5.5 WORKING SCIENTIFICALLY: Writing hypotheses (p. 182)

Investigating direct and indirect forces

5.6 Balanced and unbalanced forces (p. 185)

Balanced forces occur when the individual forces on an object cancel each other out. Unbalanced forces occur when the individual forces do not cancel each other out.

5.8 The effect of mass (p. 189)

When an object experiences a net force, its mass affects how its motion changes.

5.7 Net force (p. 187)

The sum of two or more forces is called the net force.

5.9 Mass and weight (p. 191)

The weight of an object depends on gravity and mass.

5.10 WORKING SCIENTIFICALLY: Presenting data in tables and graphs (p. 194)

Investigating weight and friction

5.12 WORKING SCIENTIFICALLY: Making predictions using cause-and-effect relationships (p. 202)

Investigating levers

5.11 Simple machines (p. 196)

Using a simple machine makes a task easier by multiplying the force applied.

5.13 ABORIGINAL AND TORRES STRAIT ISLANDER SCIENCE CONTEXTS: Spear-throwing technology (p. 204)

Aboriginal and Torres Strait Islander Peoples developed or used tools such as spear-throwers, which increase the speed and accuracy of hunting spears.

5.14 SCIENCE IN CONTEXT: Earth's magnetic field (p. 205)

Earth's magnetic field is vital to life on the planet.



ESB Professional/Shutterstock.com

Figure 5.0.1 shows some of the statues on Easter Island. It is estimated that hundreds of statues were moved into position between 650 and 400 years ago. Although they vary in size, their average mass is approximately 55 tonnes (55 000 kg) and they are about 7 metres high. Each statue has been moved several kilometres over hilly ground from where they were carved from volcanic rock.

- ▶ How could an object so huge be moved by people without sophisticated machinery?
- ▶ How can we use a knowledge of forces to overcome the challenge to lift and move heavy objects over a distance?

▲ FIGURE 5.0.1 These very heavy statues were moved several kilometres.

#5 DIVE INTO SCIENCE!

At the end of this chapter, you can complete Science in Depth Study #5. You can use the information you learn in this chapter to complete the project.

Assessments

- Prior knowledge quiz
- Chapter review questions
- End-of-chapter test
- Additional depth study: Secondary sources investigation

Videos

- Science skills in a minute: Hypotheses (5.5); Representing data (5.10)
- Video activities: Friction (5.3); What are magnets? (5.4); Measuring weight in space (5.9); Levers, wheels and pulleys (5.11)

Science skills resources

- Science skills in practice: Writing hypotheses (5.5); Collecting and representing data (5.10)
- Extra science investigations: The effect of friction (5.3); Exploring electrostatic forces (5.4); Tug-of-war forces (5.6)

Interactive resources

- Simulations: Effect of friction (5.3); Find the net force (5.7); How does mass affect force? (5.8)
- Label: Applied and reaction forces (5.1)
- Drag and drop: Classifying direct and indirect forces (5.4)



 Nelson MindTap

To access resources above, visit cengage.com.au/nelsonmindtap

5.1 What is a force?

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ list examples of forces
- ✓ list the effects of a force.



Interactive resource
Label: Applied and reaction forces

GET THINKING

Why do some things (such as an empty box or a ball) move when we bump into them? Why do other objects (such as a piano or a car) not move when we bump into them? Can you think of a key difference between these groups?

What are forces and where do they come from?

motion

the change in position of an object over time

force

a push, pull, twist or squeeze experienced by an object when it interacts with another object

Look at the objects around you. Whether those objects are in **motion** or not moving, each is doing so as a result of forces. We cannot see a **force**, but we can often observe its effects.

Pushes, pulls, twists and squeezes can all be described as forces. Pushes, pulls, twists and squeezes are all applied by one object on another object. You can see examples of pushes, pulls, twists and squeezes in Figures 5.1.1–5.1.4.



▲ FIGURE 5.1.1 By pushing the box, the child is applying a force to it.



▲ FIGURE 5.1.2 By pulling on the lead, the dog is applying a force on the person.



▲ FIGURE 5.1.3 A twist is a force.



▲ FIGURE 5.1.4 A squeeze is a force.

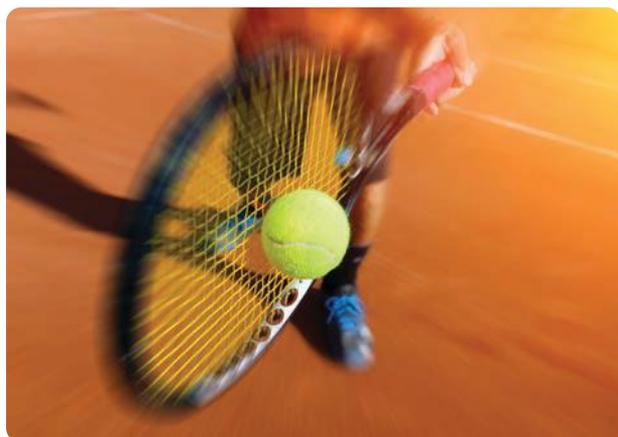
These examples all show forces that are exerted by one object on another object. This can also be described as an **interaction** between the two objects. For example, a racquet exerts a force on a ball in a tennis game; therefore, there is an interaction between the ball and the racquet (Figure 5.1.5). A wall, the ground and **gravity** each exerts a force on a ladder leaning against a wall (Figure 5.1.6).

interaction

an action that occurs as two objects have an effect on each other

gravity

a force applied by one mass on another mass



iStock.com/mikdam

▲ FIGURE 5.1.5 When a tennis racquet exerts a force on a ball, there is an interaction between the ball and the racquet.



ink Drop/Shutterstock.com

▲ FIGURE 5.1.6 The ground, the wall and gravity all exert a force on the ladder.

What do forces do and where do they come from?

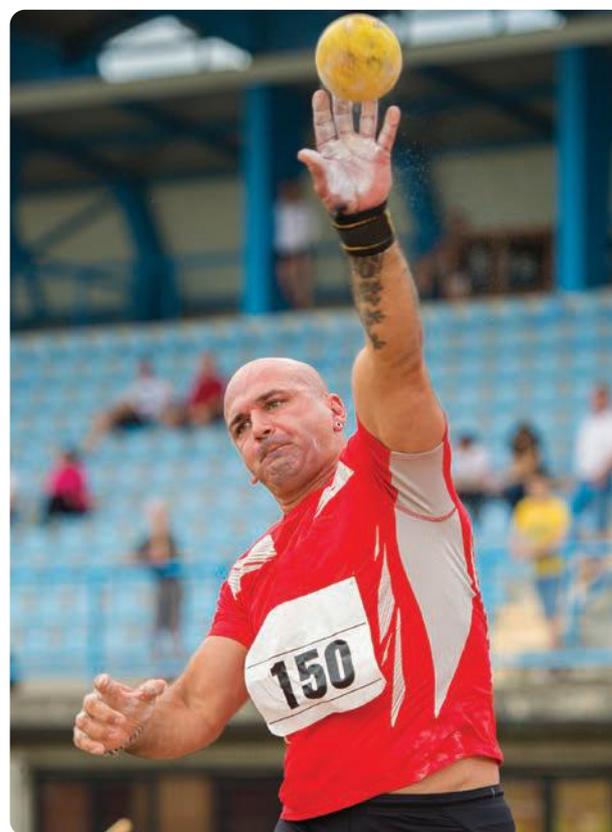
Forces can hold an object in place, such as those that are acting on the ladder in Figure 5.1.6.

A force applied to an object can result in a change in the object's shape or motion. Changes in motion include a change in:

- direction, such as when an object moves around a corner or when it bounces off a surface
- speed, such as when an object goes faster or slower.

Often, a change of direction and a change of speed both occur to an object as a result of the action of a force.

Changes of shape such as squashing a rubber ball or bending a paperclip can be complicated and will not be explored in this chapter.



iStock.com/technotr

▲ FIGURE 5.1.7 The shot-putter exerts a force on the shot (large metal ball) to change its direction and speed.

Forces come in pairs

Whenever you can identify one force acting, there must be another force acting. These forces are exactly the same size but opposite in direction and each one acts on one of the two objects in the interaction. If the force you have identified can be described in the form 'object A exerts a force on object B', then it must be true that 'object B exerts an equal force in the opposite direction on object A'. One force, usually applied by a person, animal or machine, is described as an **applied force**. The other force is described as a **reaction force**. The applied force acts on one object involved in the interaction and the reaction force acts on the other object.

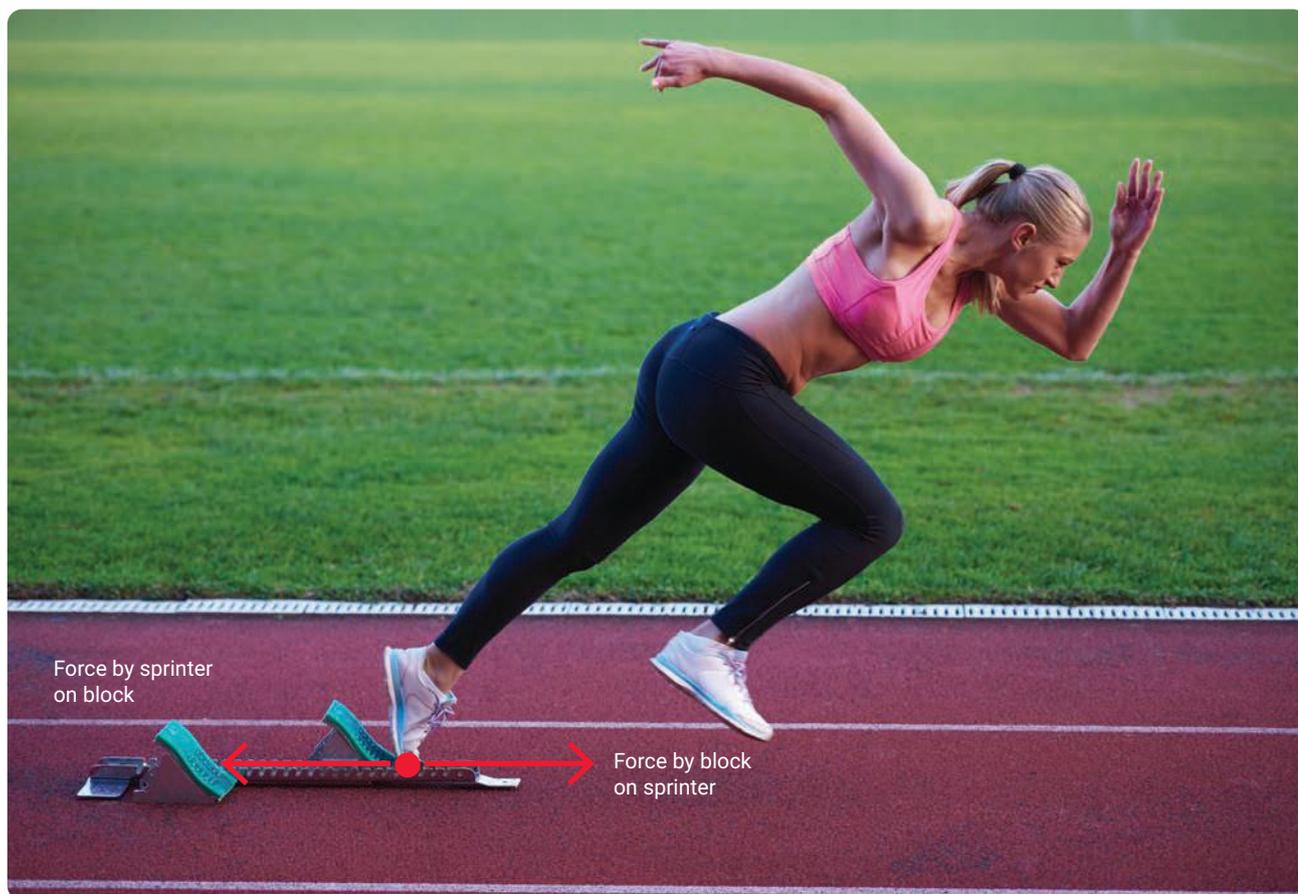
applied force

a force that is applied to an object by another object

reaction force

a force acting in the opposite direction to the applied force and on the object that exerted the applied force

For example, as a sprinter starts a race, their feet apply a backwards force on the blocks (applied force). The block applies an equal and opposite force forwards on the sprinter's feet (reaction force). This reaction force is the force that causes the sprinter to increase speed at the start of the race.



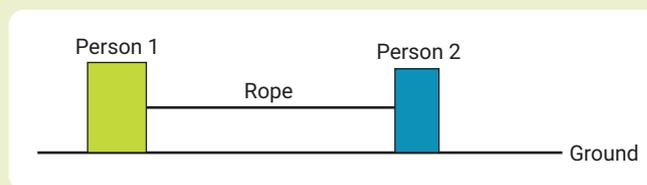
▲ FIGURE 5.1.8 The sprinter pushes back on the blocks; the blocks push forward on the sprinter.

You can remember force pairs by using a simple sentence structure such as: 'Sprinter pushes back on blocks; blocks push forwards on sprinter'. Often the second force of a pair is not obvious, but it is always there.

Extension challenge: Tug-of-war

A tug-of-war is a challenge of forces.

Imagine a simple tug-of-war with only one person on each end of the rope. Use the information you have learned about forces in this module to describe all the forces involved. A good way of doing this is to draw a simplified diagram of the two people standing on the ground with a rope between them, as shown in Figure 5.1.9, and then draw labelled arrows to represent the forces.



▲ FIGURE 5.1.9 A simple representation of two people playing tug-of-war

Recall that forces are an interaction between two objects and that each force should be part of a pair of forces, acting on one of the two objects in the interaction. The forces on each person should be the mirror of each other. How many forces have you identified and labelled on the diagram? If you have four pairs of forces – two pairs associated with each person, then you are on the right track! Check with the person next to you. When both of you are satisfied, check against your teacher's example.

In terms of the forces in the tug-of-war, how does one person win? An immediate answer might come to mind but consider a slight change to the tug-of-war set-up. Imagine person 1 is standing on slippery ground whereas person 2 is wearing boots with studs so that they have an excellent grip. It is clear that person 2 will win, but in terms of the forces in the tug-of-war, what has changed? Are you now able to give a better answer as to how one person can win this tug-of-war?

5.1 LEARNING CHECK

- 1 What is a force?
- 2 **List** three effects a force might have on an object.
- 3 Consider a book on a shelf. What forces are acting on the book and in which direction?
- 4 In one minute, **list** as many objects as you can that are *not* experiencing forces. **Compare** your list with that of a partner. Did you agree on any?
- 5 **Describe** the interactions needed to lift a pen off the desk in terms of forces applied by an object to an object.
- 6 **Identify** an applied force–reaction force pair you can see or think of. Write it in the form of 'Sprinter pushes back on blocks; blocks push forwards on sprinter'.
- 7 **Classify** the following forces as a pull, a push, a twist or a squeeze.
 - a Turning a door handle
 - b Sealing a ziplock bag
 - c Opening a drawer
 - d Sliding a calculator away from you across the desk

5.2 Measuring forces

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

✓ describe how to use a device to measure force.



Quiz
Who was Newton?

GET THINKING

Engineers and designers need to know how much force a structure or device can withstand to ensure it is safe and can do its job. Around the classroom or science laboratory, there are likely to be many objects designed to withstand a certain amount of force. Engineers and designers test these objects by measuring forces during the design process (Figure 5.2.1). How do you think they apply and measure these forces?



Sergey Ryzhov/Shutterstock.com

▲ FIGURE 5.2.1 A machine applying and measuring force during product testing

Describing force

As you learned in Chapter 1, whenever we describe a quantity, we use a number and a **unit**. The number gives information about the quantity and the unit indicates the scale of measurement. We might describe a quantity by saying ‘she jumped 3.4 metres’ or ‘he drank 200 millilitres’ or ‘I spent \$12.50’. Each of these statements uses a number and a unit. If either the number or unit is missing, the information is incomplete and unclear. Similarly, when we describe forces, we need to use a number and a unit.

Force is measured in units called **newtons**, which are often abbreviated to the capital letter N. For example, in order to lift a medium-sized book from the table, you might need to exert an upwards force on the book of 3–4 N. This unit is named after scientist Sir Isaac Newton, whose contributions to science in the 1600s enabled great progress in our understanding of forces.

unit
a fixed quantity used as a standard of measurement

newton
the unit of force (N)

spring balance
a device for measuring force; also called a force meter or newton meter

► FIGURE 5.2.2
A spring balance measuring the downwards force of a bag of potatoes



Levent Konuk/Shutterstock.com

Measuring force

Forces can be measured with a device called a force meter. It is also called a newton meter or **spring balance**. It has hooks at each end – one that is fixed and the other on a spring (Figure 5.2.2). When the fixed hook is held in place and a force is applied to the other hook, the spring stretches. The distance that the spring stretches is related to the size of the force. This means that when the force

doubles, the amount the spring stretches doubles, too. As the spring stretches, it moves a pointer on the device. The force value, in newtons, can be read from the position of the pointer against the scale.

There are also digital force meters that give a digital value of the size of a push or a pull.

Scales research project

☆ ACTIVITY



▲ FIGURE 5.2.3 Some examples of different types of scales

Perhaps you have stepped onto a set of scales to find out your weight, or you might have used a set of kitchen scales to measure ingredients for a cake. Most commonly, scales will have a digital display or a scale with lines and numbers (analogue) that moves past a pointer until it settles in a particular place.

You may have seen scales that feature a pan on either side of a central column, to which the two pans are connected by a rod that rests on the top of the column. This is called a balance scale.

You can see examples of scales in Figure 5.2.3. The scales are used to make a measurement in kilograms (kg) or grams (g), which are the units of mass.

It might surprise you to learn that mass is actually quite tricky to measure directly. So, what do these scales actually measure and how?

- 1 Research what the analogue and digital scales measure and how this measurement is used to give information about the mass of the object on the scale.
- 2 Research how forces are important in the function of the balance scale. Can you think of a way a balance scale might measure the wrong value?

5.2 LEARNING CHECK

- 1 **State** the unit of force.
- 2 Research Sir Isaac Newton and make a list of three of his contributions to science and mathematics.
- 3 **Explain** why springs and rubber bands are good at measuring forces.
- 4 **Justify** the importance of having a unit for force that is agreed on by everyone.
- 5 **Describe** how you would make your own force meter from a rubber band, a ruler, a piece of cardboard and some tape. How could you make sure the measured values were accurate? **Create** the force meter by following your own instructions. Have a class challenge to see who can make the most accurate force meter from just this equipment.

5.3 Direct forces

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe a range of direct forces
- ✓ explain the possible effects of a direct force on an object.

GET THINKING

Make a list of all the things touching you right now. Can you feel or predict the direction of the force they are exerting on you, even if it is very small? Sketch a diagram to represent the forces.

Direct forces

direct force

a force applied by one object to another object when they are touching each other

pushing force

a force applied by an object towards another object

pulling force

a force applied by an object away from another object

tension force

a force that acts to pull along a rope, cable, string, wire or chain

friction

a force that acts against the direction of motion, or intended motion, of an object because of an interaction between its surface and another surface

Many of the forces that we witness, experience or exert are **direct forces** or contact forces. A direct force is one where the object exerting the force and the object experiencing the force are in contact with (touching) each other. For example, when your finger pushes a calculator button or your hand pulls down a blind, this is a direct force. Each interaction involves objects that are in contact.

Analysing direct forces

There are several types of direct forces. Any time you can see the surface of one object touching the surface of another object, there will be a direct **pushing force**. Your finger pushing on a calculator button is an example of a direct pushing force.

A direct **pulling force** is a force such as the one you apply to lift your school bag from the floor or to drag the garbage bin along the floor. Often, direct pulling forces act along cables, strings, cords, chains or wires. The cord used to pull down a blind is exerting a direct pulling force.

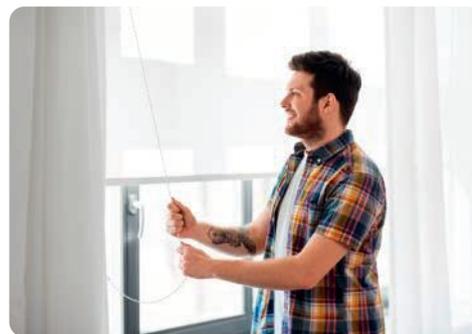
A direct pulling force that acts along things such as a cable, string, cord, chain or wire is described as a **tension force**. We might say that, in Figure 5.3.2, the tension in the cord pulling down the blind is 12 N.

Friction

Friction is a force that resists the movement of one object against another. It is a direct force that acts against the direction of motion (or intended motion) of an object.



▲ FIGURE 5.3.1 A finger exerts a direct force on a calculator button.



▲ FIGURE 5.3.2 A cord exerts a direct force pulling down on the blind.

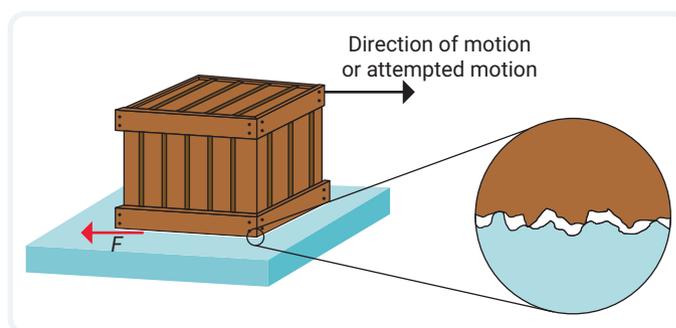
If an object is on a surface, there will be friction because of the texture of the two surfaces at a microscopic level. Even very smooth surfaces are completely covered with pits and bumps, as shown in Figure 5.3.3. When two surfaces are in contact, some of the pits of one surface inevitably fit with some of the bumps of the other. This causes friction, which prevents, or slows, motion.

Friction makes it harder to move things. This might seem like a problem, but without friction you couldn't walk, hold a pen, or manage many other actions. We rely on friction between our feet or shoes and the ground so that we don't slip and so we can push ourselves forward. We use the friction between our fingers and the pen so that we can maintain its position in our fingers while we write.

Friction often affects moving objects; however, friction is also present when objects are stationary. For example, if you were trying to move a heavy set of bookshelves across a carpeted floor, you might push very hard without causing any movement. Friction between the bookshelves and the floor would be the force that is acting to prevent the movement.

Air resistance

Air resistance is a specific form of friction. When an object such as a train is moving forward, the front of the train interacts with particles in the air. Each air particle exerts a tiny force on the train against the direction of the train's travel. The vast number of particles means that the total force opposing the motion is significant. In addition, the sides of the train move past the air. Irregularities (pits and bumps) on the side of the train provide additional opportunities for interactions with air particles, which will exert additional backwards forces. Air resistance is a form of friction that only occurs when objects are moving.



▲ **FIGURE 5.3.3** Even smooth surfaces are covered in pits and bumps that result in friction.

air resistance
friction caused by an object's motion through the air



Video activity
Friction

Interactive resource
Simulation: Effect of friction

Extra science investigation
The effect of friction

5.3 LEARNING CHECK

- 1 **List** the types of direct forces.
- 2 **Identify** three applied direct force–reaction force pairs you can see or think of. Write them in the form of 'sprinter pushes back on blocks; blocks push forwards on sprinter'.
- 3 What is tension? Use an example in your response.
- 4 **Describe** why there would be friction between the sole of your shoe and the road.
- 5 Why does air resistance increase as you move faster?
- 6 **Classify** the following situations as a push, a pull, friction, air resistance or a combination.
 - a A skydiver suddenly slows as their parachute opens.
 - b An elevator moves up a building.
 - c A chair is harder to move when someone is sitting in it.
 - d An athlete raises a weight from shoulder height to above their head.

5.4 Indirect forces

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe the key indirect forces
- ✓ describe situations in which indirect forces are observed.

GET THINKING

Why does Earth stay in orbit around the Sun? How can the Sun influence Earth when it is so far away? Discuss this with a partner and come up with a reason that you both agree on.

Indirect forces and force fields

indirect force

a force that an object exerts on another object without the objects touching each other

field

a region of space in which an indirect force exists

An **indirect force** is a force that one object can exert on another object without the objects needing to touch or be connected. Indirect forces can, therefore, act from a distance.

When one object (A) exerts a force on another object (B) without contact, we say that object A is surrounded by a **field** known as a force field. A field is a place where an object, such as object B, experiences an indirect force.

There are three types of indirect force. Two of the types of indirect forces can either attract or repel objects, depending on the circumstances, as you will see later in this module. However, the third type of indirect force always causes attraction.

Types of indirect forces

gravitational force

a force acting between two or more objects as a result of their mass

magnetic force

a force acting between two or more magnetic poles

electrostatic force

a force acting between two or more electrically charged objects

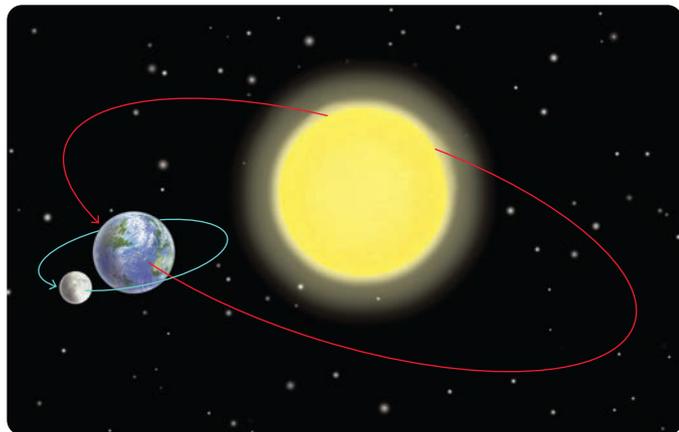
The three types of indirect forces are **gravitational force**, **magnetic force** and **electrostatic force**. You will have probably have seen, and experienced, each of these many times.

Gravitational force

Gravitational forces are indirect forces that act between all objects, attracting them to each other. Gravitational forces are often relatively weak; however, their strength depends on the mass of the two interacting objects. The greater the mass, the stronger the force. We only notice gravitational forces when they are strong enough because one of the objects

is very heavy. That is why you don't notice the gravitational force between your body and a pen, but you do notice the gravitational force between your body and Earth.

In some circumstances, gravitational force can result in an object orbiting another object, such as the planets orbiting the Sun, or the Moon and satellites orbiting Earth (Figure 5.4.1).

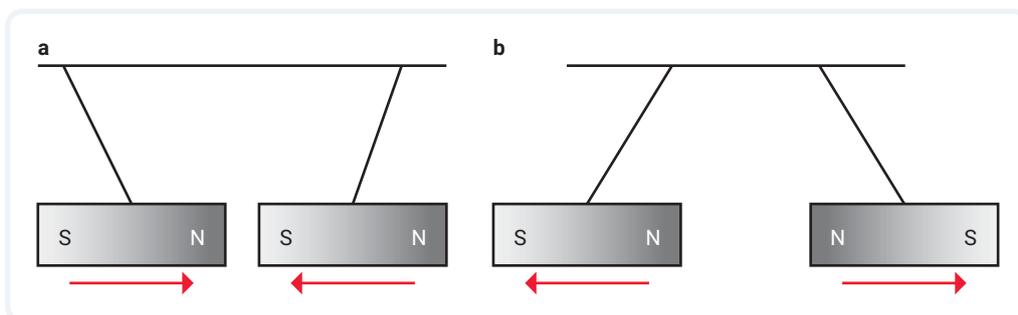


▲ FIGURE 5.4.1 Earth is attracted to the Sun by a gravitational force and the Moon is attracted to Earth by a gravitational force.

Magnetic forces

Magnetic forces are indirect forces that act between two magnetic objects. They could be two magnets or a magnet and an object that can become temporarily magnetic, such as a paperclip. Magnets can be made of a few common metals, such as iron, cobalt and nickel, or of rarer metals, such as neodymium. A **magnet** or a temporarily magnetic object has two opposite magnetic poles, called the north and south poles. The unlike poles of two magnets attract each other, so a north pole attracts a south pole of another magnet (Figure 5.4.2a). Two like poles repel each other, so any two adjacent north poles will repel (Figure 5.4.2b) and any two adjacent south poles will repel.

Magnetic forces have many applications in objects we use every day; for example, stationary bikes, fridge magnets and electric motors in fans, fridges, electric vehicles and washing machines use magnets. Magnets are also used in processes such as sorting different types of recyclable materials.



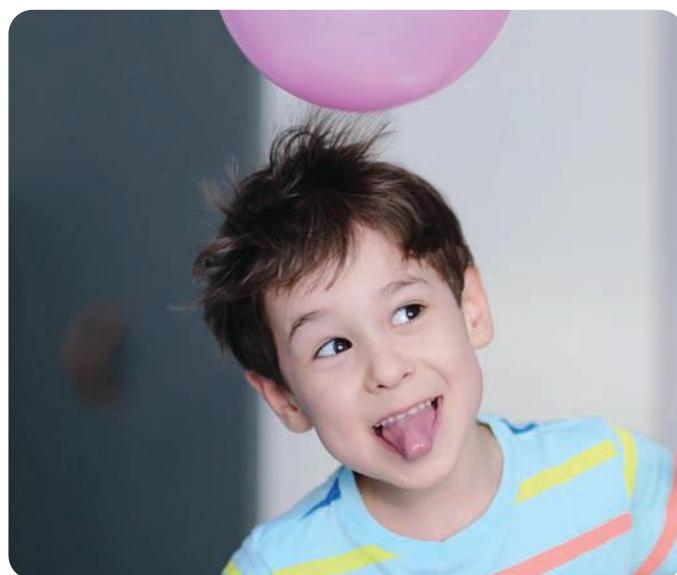
▲ FIGURE 5.4.2 (a) The south pole of one magnet and the north pole of an adjacent magnet attract each other. (b) The two north poles of adjacent magnets repel each other.

Electrostatic forces

Electrostatic forces are indirect forces that act between two objects that have electrical charges. You see this force when you use friction to make an object charged, such as by rubbing a balloon on your hair (Figure 5.4.3). The friction results in the balloon becoming negatively charged and your hair becoming positively charged. The balloon and your hair then exert an equal and opposite force on each other that causes them to attract each other.

Features of indirect forces

Objects that have mass are surrounded by a gravitational field. You have a gravitational field, but it is very weak because your mass is small. Earth has a gravitational field that is much, much stronger and so the indirect gravitational forces it exerts are greater and more noticeable.



▲ FIGURE 5.4.3 The boy's hair and the balloon are attracted to each other by electrostatic forces.

magnet

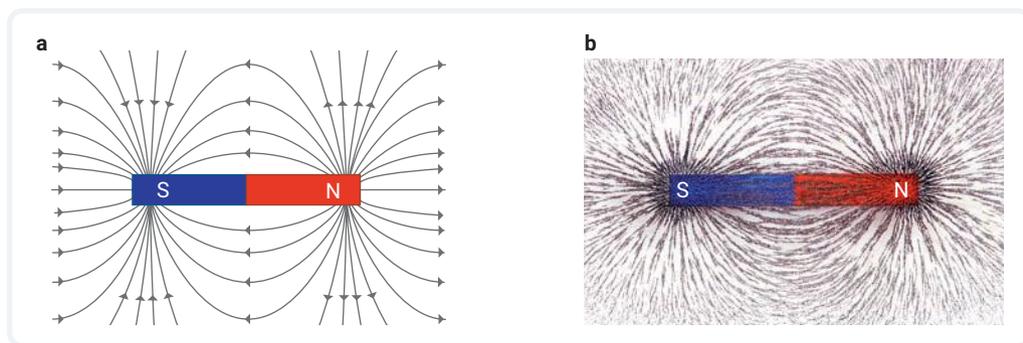
a material that produces a magnetic field



Video activity
What are magnets?

Interactive resource
Drag and drop:
Classifying direct
and indirect forces

**Extra science
investigation**
Exploring
electrostatic forces



Phil Degginger/Alamy Stock Photo

▲ **FIGURE 5.4.4** The magnetic fields surrounding a magnet. The field is strongest where the lines are closest together. The arrows show the direction of the force on a north pole placed in the field.

DATA SCIENCE



Learn more about scientific models in **Module 2.9**.

Objects that are magnetic are surrounded by a magnetic field. If another magnetic object is placed in this magnetic field, it will experience an indirect magnetic force.

A simple magnetic field, such as the one in Figure 5.4.4a, can be modelled by placing a magnet under an A4 sheet of paper. When you sprinkle iron filings over the paper, they move into a pattern that shows the field lines (Figure 5.4.4b).

Objects that are electrically charged are described as being surrounded by an electric field. If another electrically charged (positive or negative) object is placed in this electric field, it will experience an indirect electrostatic force.

Effect of indirect forces

Gravitational fields always exert an **attractive force** on any object. No object is repelled when it enters Earth's gravitational field. However, magnetic and electric fields can exert **repulsive forces** as well as attractive forces.

Whether the force exerted in a magnetic or electric field is attractive or repulsive depends on the source of the field and the object placed in the field.

If a north pole is placed into the field surrounding another north pole, it will be repelled. A south pole placed at the same point in that field will be attracted. These forces were shown in Figure 5.4.2. The easy way to remember the type of force that will occur is to use the saying 'like poles repel and unlike poles attract'.

Similarly, with electric charges, a negative charge placed into a field around a positive charge will experience a force of attraction. A positive charge placed in a field created by a positive charge will experience a force of repulsion.

Each of these indirect forces gets weaker as the distance between the source of the field and the object is increased.

attractive force

an indirect force that brings two objects closer together

repulsive force

an indirect force that pushes two objects away from each other

Extension challenge experiment

Tear a small piece of dry scrap paper into 10–20 very small pieces. Now rub a plastic ruler or an inflated rubber balloon vigorously against a woollen jumper or a polar fleece. Rubbing an object like this can make it electrically charged. Hold the part of the balloon or ruler that has been rubbed about 1 cm above the pieces of paper.

Write down what you observe about the pieces of paper.

The reason the paper moves the way it does is quite complex.

In this module, you have learned that:

- 1 like charges repel and unlike charges attract due to the electrostatic force.
- 2 the electrostatic force gets weaker the further apart the two charged objects are.

You also need to know that:

- 3 within each tiny piece of paper some (about 1 in every 100) negative charges are able to move.

These three facts are all you need to explain the observations you made about the pieces of paper.

Keep in mind that, although the balloon or ruler is charged, the pieces of paper are not charged (overall they are neutral).

Draw an enlarged diagram of a single piece of the torn paper. Above it, draw the ruler or balloon as appropriate to your challenge. Assume that the ruler or balloon has become negatively charged when it was rubbed. Challenge yourself to use the diagram and the three facts to explain what you observed.

5.4 LEARNING CHECK

- 1 **State** the name of the region where a:
 - a mass exerts an indirect force on other masses.
 - a charged object exerts an indirect force on another charged object.
 - a magnet exerts a force on another magnet.
- 2 A red balloon is given a positive charge. It is observed that a blue balloon is attracted to the red balloon but that it is repelled by a green balloon. What type of charge does the:
 - a blue balloon have?
 - b green balloon have?
- 3 **Explain** why gravity is considered to be an indirect force. Use an example in your answer.
- 4 **Compare** the three types of indirect forces to determine what magnetic and electrostatic forces have in common that is not shared by gravitational forces.
- 5 The needle of a compass is a small magnet that can spin on an axis and that always points in the same direction. What can you infer about Earth from this observation?
- 6 Think about where you have been today, what you have touched, and what you have done since you woke up this morning. **Evaluate** the role of the three types of indirect forces you have encountered so far today. Make a list of two strengths and two limitations of each type of force in the context of your day.



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THIS SKILL:

- ▶ write a hypothesis.

A hypothesis is a testable explanation for something based on existing knowledge. It states the link between the independent variable (what is being changed) and the dependent variable (what is being measured).

How to write a hypothesis

- 1 Identify the dependent variable – what are you measuring or observing?
- 2 Identify the independent variable – what are you changing?
- 3 How do you think changing the independent variable will affect the dependent variable?

Often, you can write a hypothesis with an 'If . . . , then . . .' statement, as seen in Figure 5.5.1.

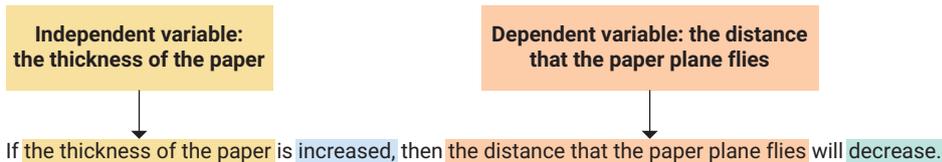
For example, if we want to test the question 'Does the thickness of paper change how far a paper plane flies?', then the hypothesis might be 'If the thickness of the paper is increased, then the distance that the paper plane flies will decrease'.

You will practise writing hypotheses for the investigations on magnetic fields and direct and indirect forces.



Video
Science skills
in a minute:
Hypotheses

**Science skills
resource**
Science skills
in practice:
Writing
hypotheses



▲ FIGURE 5.5.1 An example of a hypothesis

INVESTIGATION 1: MAGNETIC FIELD STRENGTH AND DISTANCE

BACKGROUND INFORMATION

Earth's magnetic field will cause a compass needle to align itself north–south. In this investigation, you will determine how the relative strength of a magnet influences the distance at which its magnetic field can overcome the magnetic field of Earth. You will change the relative strength of the magnet by increasing the number of magnets used.

AIM

To investigate the relationship between the strength of a magnetic field and the distance from the magnet

MATERIALS AND EQUIPMENT

- 1-metre ruler
- compass
- 4 bar magnets
- tape

PROCEDURE

- 1 Write a hypothesis for this investigation, following the steps outlined in the 'Science skills in focus' box.
- 2 Find a horizontal surface on a desk away from any objects containing metal, such as chairs or tables. (Metal objects can interfere with how the compass needle aligns.) Check the compass needle consistently aligns north–south. If it doesn't, find a new location for your experiment.
- 3 Place the compass on top of the metre ruler so that the needle is perpendicular to the ruler at the 50 cm mark, as shown in Figure 5.5.2.
- 4 Place a magnet on the 0 cm end of the ruler so that the north pole points along the ruler at the compass.
- 5 Slowly move the magnet along the ruler towards the compass until the compass needle swings around and points at the pole of the magnet. When this occurs, stop moving the magnet and measure its distance from the compass. Record the distance in the results table.
- 6 Repeat step 5 twice, until you have data for three trials. Use the data in the table to calculate the average for the three trials. Record the average in the results table.
- 7 Tape a second magnet beside the first one, making sure both north poles are at the same end.
- 8 Repeat steps 5 and 6.
- 9 Tape a third magnet to the first two. Ensure all north poles are at the same end.
- 10 Repeat steps 5 and 6.

- 11 Tape a fourth magnet to the other three magnets. Again, ensure all north poles are at the same end.
- 12 Repeat steps 5 and 6.

RESULTS

Record your data in the table below.

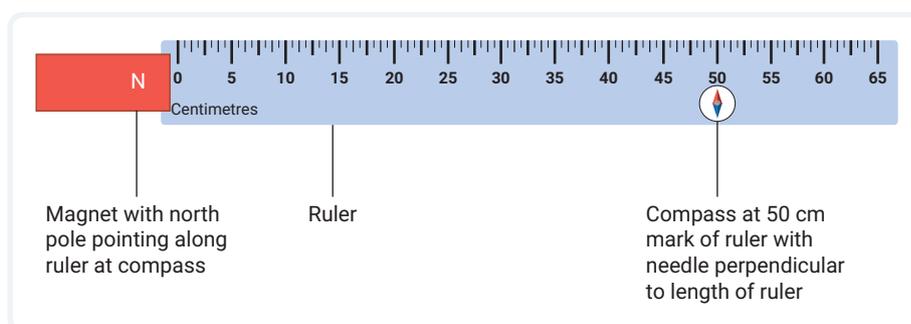
Number of magnets	Distance of magnets from compass			
	Trial 1	Trial 2	Trial 3	Average
1				
2				
3				
4				

ANALYSIS

- 1 What do you notice about the average distance values as the number of magnets increases?
- 2 Does this match your hypothesis?
- 3 Can you predict the distance at which eight magnets would influence the compass needle?
- 4 What are some problems with making this prediction from the data you have collected?

CONCLUSION

Write a conclusion for this experiment. Remember to state if your results support your hypothesis.



▲ FIGURE 5.5.2 The experimental set-up for the investigation

INVESTIGATION 2: ELECTROMAGNETISM

BACKGROUND INFORMATION

You can extend the magnetic field experiment by using an electromagnet in place of the bar magnet. An electromagnet is a magnet that has its magnetic field produced by an electric current.

AIM

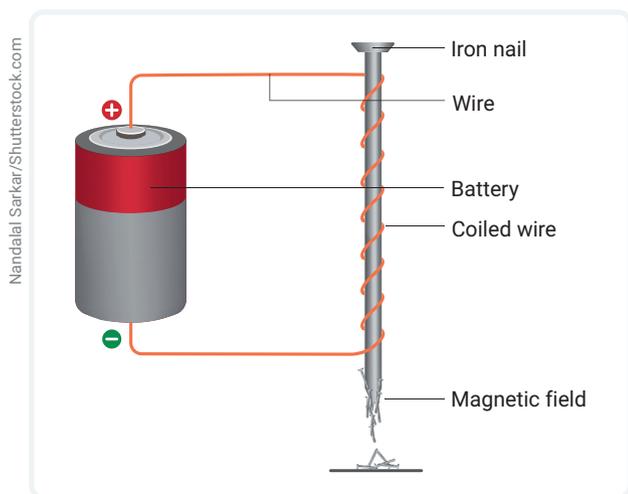
To investigate the relationship between the strength of a magnetic field of an electromagnet and the distance from the magnet

MATERIALS AND EQUIPMENT

- ☑ materials for electromagnet: battery, iron nail, copper wire
- ☑ compass
- ☑ 1-metre ruler

PROCEDURE

- 1 Make an electromagnet by:
 - a wrapping insulated copper wire around an iron nail.
 - b connecting the ends of the copper wire to the terminals of a battery as shown in Figure 5.5.3.



▲ FIGURE 5.5.3 A simple electromagnet

The strength of the electromagnet is dependent on the number of loops of wire wrapped around the iron nail. The ends of the iron nail will become the magnetic poles.

- 2 Write a hypothesis for this investigation, following the steps outlined in the 'Science skills in focus' box.
- 3 Make the electromagnet stronger by increasing the loops of wire around the nail.
- 4 Repeat step 5 from Investigation 1 by slowly moving the magnet along the ruler towards the compass until the compass needle swings around and points at the pole of the magnet. When this occurs, measure its distance from the compass and record the measurement in a table.
- 5 Repeat step 4 twice, until you have data for three trials. Use the data in the table to calculate the average for the three trials. Record the average in the results table.

ANALYSIS

- 1 Did your results support your hypothesis?
- 2 How were the results for this experiment different from your original investigation? Explain any similarities or difference in the results.
- 3 Can you predict what would happen if you further increased the number of loops around your electromagnet?
- 4 What are some problems with making this prediction from the data you have collected?

CONCLUSION

Write a conclusion for this experiment. Remember to state if your results support your hypothesis. Link this conclusion to your findings from the original investigation.

5.6 Balanced and unbalanced forces

5.6

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

✓ explain the effect of balanced and unbalanced forces.

GET THINKING

Look at Figure 5.6.1, which shows a man pulling a tyre. What forces are acting on the tyre? Can you explain what would need to be true of those forces if the tyre is moving at a constant speed or if the tyre is slowing down? What about if the tyre is speeding up?



PixelMe/Shutterstock.com



Quiz
Balanced or unbalanced force?

Extra science investigation
Tug-of-war forces

▲ FIGURE 5.6.1 What forces act on the tyre as the man drags it across the grass?

Distinguishing balanced from unbalanced forces

Figure 5.6.2 shows a busy street. All of the objects shown have many different forces acting on them. Some objects are stationary and others are moving. Whether they are stationary or moving, and how they are moving, depends on the forces acting on them.

In some of the situations, we would describe the forces as **balanced forces**, and in others we would describe the forces as **unbalanced forces**. You may be able to work out some of the forces acting on the objects using the knowledge you have gained so far in this chapter.

balanced force

a force that has an equal force acting on the same object in the opposite direction

unbalanced force

a force that does not have an equal force acting on the same object in the opposite direction



Kumar Srisikandam/Alamy Stock Photo

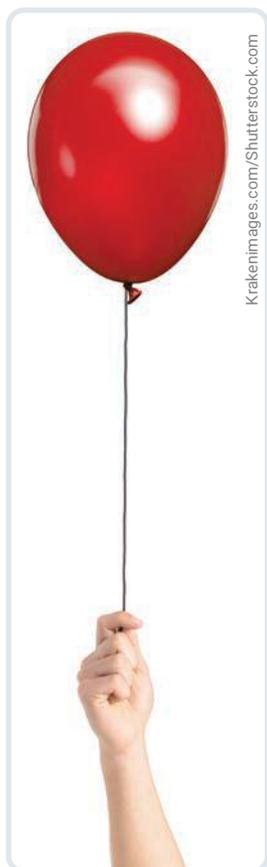
▲ FIGURE 5.6.2 A busy street: there are many forces acting.

buoyancy

the upward force exerted by a liquid on an object

▼ FIGURE 5.6.3

A stationary balloon on the end of a string is under the influence of gravity, tension and buoyancy. The three forces are balanced.



Consider the forces acting on the balloon in Figure 5.6.3. The balloon would be experiencing:

- a force due to gravity acting downwards
- tension in the string acting downwards
- a force due to the air acting upwards (**buoyancy**).

The two downwards forces cancel out the upwards force and so we can say that the forces are balanced.



▲ FIGURE 5.6.4 A falling bottle is under the influence of unbalanced forces.

Consider a plastic bottle being dropped into the recycling bin, as shown in Figure 5.6.4. The force of gravity will, of course, act downwards on it. The only other force is a small force upwards caused by air resistance. Because the downwards force is greater than the upwards force, the forces do not cancel out. These forces are said to be unbalanced.

Effect of balanced and unbalanced forces

A simple way to tell if the forces acting on an object are balanced or unbalanced is to analyse the motion of the object.

- If the object is stationary, or is moving at constant speed, then the forces must be balanced.
- If the object is getting faster, slowing down or changing direction, then the forces must be unbalanced.

5.6 LEARNING CHECK

- 1 What types of motion indicate that an object is under the influence of balanced forces?
- 2 Consider the objects seen on the street in Figure 5.6.2.
 - a **Identify** two objects that are under the influence of balanced forces.
 - b **Justify** your choices in part a.
- 3 **Describe** the forces acting on the suitcase shown in Figure 5.6.2.
- 4 If a car is slowing down, **state** what must be true about the forces acting on the car. Consider the sizes of the forwards and backwards forces acting on the car.
- 5 **Explain** the types of motion that show an object is under the influence of unbalanced forces.

5.7 Net force

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ represent forces in a diagram
- ✓ describe how to determine the net force on an object.

GET THINKING

Think of a time you pushed or dragged a heavy object over a rough surface; for example, a box full of books across a carpet. You might have pushed and at first it didn't move, so you pushed a bit harder, and suddenly it started moving. In terms of the forces involved, suggest why the box didn't move at first, but then began moving.



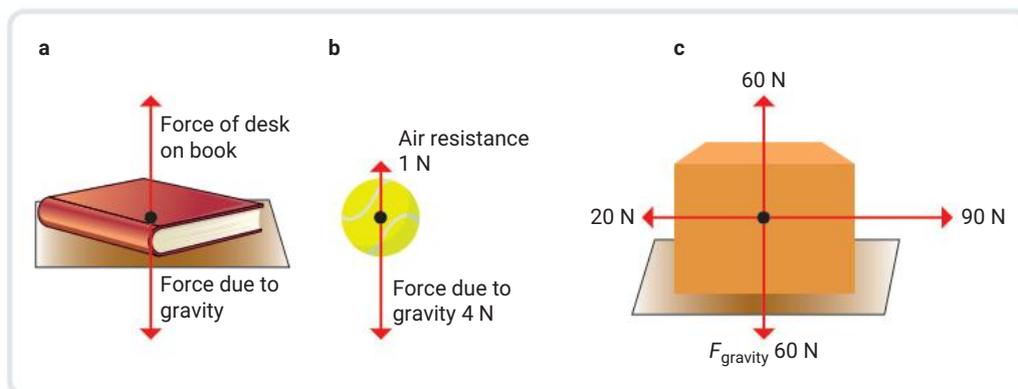
Interactive resource
Simulation: Find the net force

Representing forces

To describe or analyse the forces acting on an object, it is helpful to draw a simple diagram that includes all the forces. Each force is represented by an arrow that points in the direction of the force. This arrow is called a **force arrow**. The length of a force arrow indicates the strength of the force – a longer force arrow indicates a larger force. Labelling the force arrows with the type of force helps to make the diagram more informative.

force arrow

an arrow drawn on a diagram to illustrate the direction and relative strength of a force



▲ FIGURE 5.7.1 Forces acting on (a) a book at rest on a desk; (b) a falling tennis ball; (c) a box being pushed along a floor

Adding forces to find net force

Forces acting on an object add up to create a **total force** (or **net force**). If the forces cancel out, the forces are balanced and the net force is zero.

total force (net force)

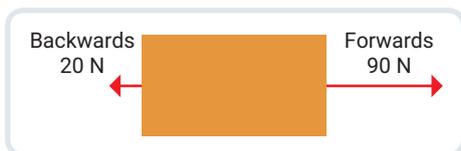
the sum of all forces acting on an object

In Figure 5.7.1a, the downwards force due to gravity acting on the book is equal in size and opposite in direction to the upwards force from the desk acting on the book. The forces acting on the book are balanced and the net force on the book is zero.

In Figure 5.7.1b, the downwards force acting on the tennis ball due to gravity is much bigger than the upwards force acting on the ball due to air resistance. These forces are not balanced – there will be a net force downwards because the larger force is the downwards one. The size of the net force depends on the size of the two forces acting in this case. You can see that the upwards force due to air resistance is 1 N and the downwards force due to gravity is 4 N, so the net force is 3 N downwards.

In Figure 5.7.1c, the force upwards and the force downwards are balanced (and so the net force in the up and down direction is zero). Because of this, the net force on the box can be determined by just looking at the forwards and backwards forces. The forwards push force of 90 N is larger than the backwards frictional force of 20 N. The net force is found by subtracting the forces because they are acting in opposite directions on the box. This results in a net force of $90\text{ N} - 20\text{ N} = 70\text{ N}$ forwards. This is shown in Figure 5.7.2.

If two forces are acting in the same direction, then the net force can be found by adding the forces. A backwards push of 50 N and a pull in the same direction of 20 N will result in a net force of $50\text{ N} + 20\text{ N} = 70\text{ N}$ backwards. This is shown in Figure 5.7.3.



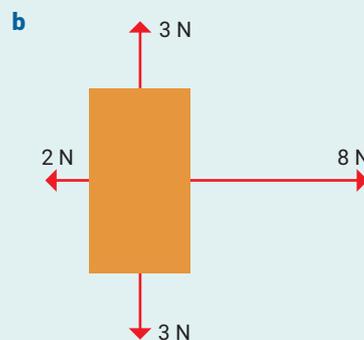
▲ **FIGURE 5.7.2** The forces are acting in opposite directions. Therefore, the net force is found by subtracting the backwards force from the forwards force.



▲ **FIGURE 5.7.3** The forces are acting in the same direction. Therefore, the net force is found by adding the forces.

5.7 LEARNING CHECK

- 1 **Identify** another term for net force.
- 2 For each example, **calculate** the net force and **describe** a motion that might result from the net force.



- 3 **Draw** a labelled diagram representing the forces acting on an object you can see that is:
 - a stationary.
 - b moving.
- 4 **Describe** three types of motion that indicate that the net force on an object is not zero.
- 5 An object has the following forces acting on it: 4 N up, 6 N left and 4 N down. What force must be added so that the net force is zero?
- 6 Reflect on your response to the Get thinking activity at the start of the module. Can you **explain** it better now?
- 7 Take a video that includes footage of a stationary object, an object moving at a constant speed and an accelerating object. Add a commentary to explain what is happening in terms of the forces acting on each object.

5.8 The effect of mass

5.8

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define mass
- ✓ describe how mass affects the motion of an object experiencing a net force.

GET THINKING

A bowling ball is smaller than a basketball and yet it is harder to pick up. What does a bowling ball have that makes this the case?



▲ FIGURE 5.8.1 Why is a bowling ball harder to pick up than a basketball?



Interactive resource
Simulation: How does mass affect force?

What is mass?

You will recall from Chapter 3 that **mass**, which is measured in milligrams (mg), grams (g) or kilograms (kg), is the amount of matter that makes up an object. Objects that have more matter have greater mass. As is shown in Figure 5.8.2, an apple has more matter, and therefore mass, than a cupcake, even though they may be the same or similar size.

mass
the amount of matter in an object, measured in kilograms (kg), grams (g) or milligrams (mg)

The effect of mass

You know from previous modules that when an object experiences an unbalanced or net force, its motion changes – it speeds up, slows down or changes direction. How much it changes will depend on the mass of the object.

For example, consider the case of a toy car and a real car (Figure 5.8.3). If both were rolling down a hill towards you, it would be much easier to apply a force to stop the toy car than to stop the real car. This is because the toy car has a much smaller mass.



▲ FIGURE 5.8.2 The apple has more mass than the cupcake even though they are a similar size.



▲ FIGURE 5.8.3 Less force would be needed to stop the toy car than to stop the heavier real car.

We can express this in a general statement: if the same net force is applied to two objects of different mass, the one with the smaller mass will experience a greater change in motion.

This explains why it is easier to throw a tennis ball than a cricket ball, why it would hurt less if a peanut fell on you than if a coconut did, why it is easier to push a child on a swing than a large adult, and why it is easier to pick up a pebble than a boulder.



▲ **FIGURE 5.8.4** It is easier to change the motion of a child on a swing than it would be to change the motion of an adult on a swing. This is because the child has less mass.

5.8 LEARNING CHECK

- 1 **Write** a sentence to tell someone what mass is, without using the word 'matter'.
- 2 Which has more mass – a kilogram of feathers or a kilogram of metal? **Justify** your answer.
- 3 Does air have mass? **Discuss** with a friend. **Justify** your response.
- 4 Truck drivers know to leave a bigger gap between them and the vehicle in front when they have a full load than when their truck is empty. **Explain** why this is important for safety.
- 5 **Explain** why it is easier to swing a bucket in a circle when it is empty than when it is full of water.
- 6 Extension: Consider a heavy object that you can move by hand. This might be a 2 L carton of milk, a bowling ball, a big book or something completely different but similarly heavy. Now imagine lifting the object, with one hand, from the floor to above your head. Think about how much effort that would require. Next imagine pushing the object, with one hand, to make it slide away from you as fast as you could across a very, very smooth surface. Think about how much effort that would require. If you repeated each of these two 'thought experiments' inside a spaceship in deep space – a long way from any stars or planets – would each require the same effort, more effort or less effort? Why? Try to use the word 'mass' in your response.

5.9 Mass and weight

5.9

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ calculate the weight of an object of known mass in a given gravitational field
- ✓ explain why mass remains constant but weight may change when location changes.

GET THINKING

Figure 5.9.1 shows an astronaut walking on the Moon. How would walking on the Moon differ from walking on Earth? Why?



Dennis Hallinan/Alamy Stock Photo

▶ **FIGURE 5.9.1** Walking on the Moon is different from walking on Earth.



Video activity
Measuring weight in space

Weight versus mass

A 1.5 kg tub of ice-cream would have a mass of 1.5 kg here on Earth and on the Moon. The mass of the ice-cream stays the same because the amount of matter is the same. However, the **weight** of the ice-cream on the Moon would be much less than it is on Earth.

Weight is the downwards force on an object due to gravity. We also describe weight as the force experienced by an object in a gravitational field. Weight is a force and, therefore, is measured in newtons. All objects around you have a:

- mass because they have matter
- weight due to the force exerted by gravity.

Changing weight

Because weight is the force downwards on an object due to gravity, it depends on the mass of the object and the amount of gravity. The amount of gravity is described by the term '**acceleration due to gravity**'. This is a measure of how quickly the speed increases when an object falls. The acceleration due to gravity, represented by the symbol 'g', is described by a number and the units m/s^2 (metres per second squared). The acceleration due to gravity is different in different places in the solar system (Figure 5.9.2), although it is nearly the same at all places on Earth.

Weight can be calculated by multiplying mass by acceleration due to gravity.

$$\text{Weight} = \text{mass} \times \text{acceleration due to gravity}$$

The acceleration due to gravity on Earth is 9.8 m/s^2 . So, the weight of a 5 kg mass on Earth can be calculated using the equation above.

$$\text{Weight} = 5 \text{ kg} \times 9.8 \text{ m/s}^2 = 49 \text{ N}$$

weight

the downwards force on an object due to gravity

acceleration due to gravity

the rate at which a falling object gets faster due to the force of gravity



Earth
 $g = 9.8 \text{ m/s}^2$



Moon
 $g = 1.6 \text{ m/s}^2$



Jupiter
 $g = 24.8 \text{ m/s}^2$

Dotted Yeti/Shutterstock.com

▲ **FIGURE 5.9.2**
Gravity has different values on Earth, the Moon and Jupiter.

The acceleration due to gravity on the Moon is 1.6 m/s^2 . So, the weight of a 5 kg mass on the Moon is:

$$\text{Weight} = 5 \text{ kg} \times 1.6 \text{ m/s}^2 = 8 \text{ N}$$

Extending this idea, we can see that if you move an object that has a constant mass to a range of places with different gravity (such as the Moon, Mars, Mercury and Jupiter), the weight will be different in each place.



▲ FIGURE 5.9.3 An astronaut will have the same mass on the Moon as on Earth but a different weight.

☆ ACTIVITY

Weightlessness or zero gravity

Science fiction movies often have scenes in which the characters or objects in or around a spacecraft seem to float as if they are weightless or there is no gravity.

Movies such as *Gravity*, *The Martian* or *Apollo 13* all feature very realistic and scientifically accurate versions of this.

Alternatively, YouTube videos show astronauts on the International Space Station (ISS) experiencing this apparent weightlessness or zero-gravity feeling.

What do you think?

The terms 'weightlessness' and 'zero gravity' are often used to describe these scenes, but are these terms correct?

- 1 Using what you have learned in this module about weight and gravity, discuss with a classmate whether having no weight or finding a place where there is no gravity is possible.

In your discussion, you might have considered the Moon, which orbits Earth because of the effect of Earth's gravity, or the planets of our solar system, which orbit the Sun because of the effect of the Sun's gravity. These examples tell us that there is gravity acting throughout our solar system. The ISS is only a few hundred kilometres from Earth's surface (the movie *Gravity* is set in a similar location).

- 2 How does it seem that there is no gravity and, therefore, no weight on the ISS and in the movie *Gravity*?

To help you answer this question, imagine a situation in which you are in an elevator at the top of the tallest building in the world. You are standing on a set of bathroom scales, and you are holding an apple in your hand in front of your face. You can feel the weight of the apple and you know if you let go of it the apple would fall to the floor of the elevator. The bathroom scales indicate your mass because you are pressing down on them – you can feel that pressure in your feet.

Suddenly the cable holding the elevator breaks and you are falling straight down. As you fall, you notice that the 'feel' of the apple has changed, as has the feel of your feet on the scales.

- 3 If you look down at the scales, what would you see? If you dropped the apple, what would you see? Discuss this with a classmate.
- 4 Check with the teacher to see if you are correct.
- 5 Now look at the question about the ISS again. How would you explain the apparent weightlessness to a friend or family member now?



▲ FIGURE 5.9.4 Astronauts on the International Space Station experience apparent weightlessness.

5.9 LEARNING CHECK

- 1 Write two different phrases to describe 'acceleration due to gravity' in your own words.
- 2 **Discuss** whether we use the term 'weight' correctly.
- 3 **Calculate** the weight of a 50 kg boy on Mars where the acceleration due to gravity is 3.7 m/s^2 .
- 4 **Compare** the meaning of the terms 'weight' and 'mass'.
- 5 Use what you learned in Module 5.4 about how Earth's gravitational field changes as you get further from Earth to **predict** where on Earth your weight would be least. **Explain** your answer.
- 6 Challenge: **Calculate** the mass of an object if its weight is 120 N on Earth.



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ organise data in an effective table
- ▶ analyse data using a graph to determine a mathematical relationship.

Tables and graphs are important and powerful tools for organising and analysing data. In chapters 1 and 2 you looked at making tables and graphs. In this module, you will practise and refine those skills.

Recall that all tables have:

- 1 an informative title
- 2 ruled columns
- 3 column headings that describe the data
- 4 units for the data only in the column heading (in brackets)
- 5 the independent variable (the one you changed) in the first column
- 6 the dependent variable (the one you measured) in the next columns.

Recall that all graphs have:

- 1 an informative title
- 2 ruled axes
- 3 a numerical scale that increases in even increments
- 4 labels for axes that describe the data
- 5 units for axes in brackets next to the label
- 6 the independent variable (the one you changed) on the horizontal axis
- 7 the dependent variable (the one you measured) on the vertical axis
- 8 average results only (in most cases)
- 9 a line (or curve) of best fit.

Always make your graph occupy as much of the grid space as possible.

DATA SCIENCE



Learn more about dataset preparation and data summaries in **Module 2.7**.

THE RELATIONSHIP BETWEEN WEIGHT AND FRICTION

AIM

To determine the relationship between the weight of an object and the force of friction that acts on the object

MATERIALS AND EQUIPMENT

- spring balance
- wooden block with a hook on one end or string attached to it
- frictional surface such as a wooden plank, piece of carpet or piece of sandpaper
- range of masses increasing in small increments from 250 g to 1 kg
- electronic balance

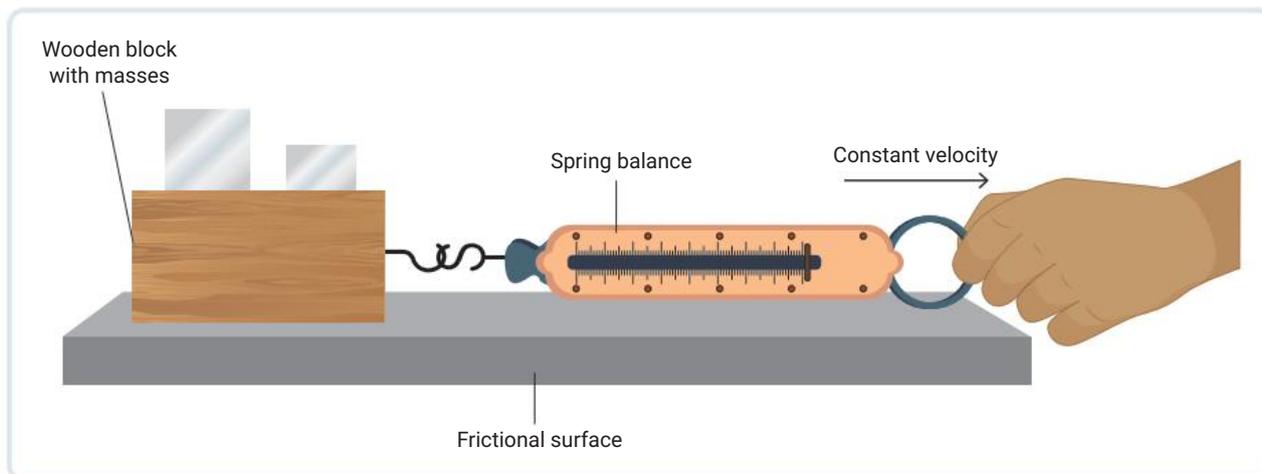
PROCEDURE

- 1 Write a hypothesis for this investigation.
- 2 Set up the equipment as shown in Figure 5.10.1.
- 3 Design a table to record the force needed to move the block with different added masses.
 - a Label the first column 'Total mass'. Label the second column 'Calculated weight' and the third column 'Force measured'. Divide the third column into four sub-columns for trial 1, trial 2, trial 3 and average values. Include the unit of measurement for each column.
 - b Ensure you have enough rows for the number of masses you plan to add during the investigation.
- 4 Measure and record the mass of the block on the electronic balance.



Video
Science skills
in a minute:
Representing data

**Science skills
resource**
Science skills in
practice: Collecting
and representing
data



▲ FIGURE 5.10.1 A spring balance is used to measure the force required to pull a mass along a surface.

- 5 Attach the spring balance to the hook or string on the block. Slowly and steadily drag the block along the frictional surface. Record the force required to move the block. Note that this force may vary slightly, up and down, during the motion. Record the value that represents the middle or most consistent value.
- 6 Add a mass to the block.
- 7 Measure and record the mass of the block plus one added mass on the electronic balance.
- 8 Repeat step 5.
- 9 Continue to add masses and record force values until you have used all the masses or have at least five separate mass values.
- 10 Repeat the entire process so that you have three trials for each of the mass values you use.
- 11 Calculate the weight of each of the mass values in the first column. Record these values in the second column.
- 3 Calculate the average value of the force recorded for each mass and complete that column of the table.
- 4 Draw a graph of the weight being pulled and the average force required.
 - a Label and include units for the axes and give the axes an even scale so that your data takes up as much of the graph as possible.
 - b Include an appropriate title (which can be the same as the table).
 - c Plot your data.
 - d Draw a line of best fit.
- 5 What relationship does the graph suggest between the weight of the pulled object and the average force needed to pull it at a steady rate?
- 6 How did plotting a graph and drawing a line of best fit help identify the trend?
- 7 How can you explain your results in terms of the model of friction described earlier in this chapter?

ANALYSIS

- 1 Why does the value of the force recorded by the spring balance vary a little as you drag the mass?
- 2 What was the purpose of repeating the experiment three times for each mass?

CONCLUSION

Write a conclusion that links your findings and data analysis to the hypothesis. Was the hypothesis supported?

5.11 Simple machines

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ identify simple machines
- ✓ explain how simple machines can change the size of a force needed.



Video activity
Levers, wheels and pulleys

Interactive resource
Match: Simple machines

GET THINKING

Look at Figure 5.11.1. The wheelbarrow and ramp are machines used to make it easier for a builder to move rubble up into the skip bin than if they lifted and carried the rubble in their arms. Think about the forces needed to move the rubble into the skip. How do these machines make this task easier?



Ben Schonewille/Shutterstock.com

▲ **FIGURE 5.11.1** A builder has used a wheelbarrow and ramp to move the rubble up into the skip bin.

What is a simple machine?

Have you ever wondered how a wheelbarrow or scissors make life easier?

Throughout history, people have developed machines to make difficult tasks easier, or otherwise impossible tasks achievable. Hammers, chisels, scissors, ramps and wheelbarrows use **simple machines** to perform their function. There are six simple machines from which machines are designed:

- **inclined plane**
- **wedge**
- **screw**
- **wheel and axle**
- **pulley**
- **lever.**

The main purpose of a simple machine is to increase the size of the applied force, also known as the 'effort force' or simply 'effort'. For example, a 10N force applied using a simple machine can move an object that would otherwise require 50N of force to be moved. Simple machines can also perform one or more of the following functions at the same time:

- enable a force to be applied in one place but act in another place
- change the direction of a force.

simple machine

a device that can increase the size of an applied force

inclined plane

a sloping ramp

wedge

a triangular-shaped tool tapering to a thin edge that acts as a portable inclined plane

screw

a long, inclined plane wrapped around a solid cylinder

wheel and axle

a solid rod connected to a wheel

pulley

a wheel on an axle that enables a change in direction of a rope or cable

lever

a solid plank or bar that rotates about a point

How do simple machines help us?

If we wanted to lift a heavy object into the back of a truck, we would need to apply a force (to overcome the force of gravity) over the distance from the ground to the back of the truck. When a force is applied to an object as it moves over a distance, **work** is done. The amount of work done is the product of the force applied and the distance moved. Work is measured in units of joules (J).

work
energy that is being transferred or transformed

$$\text{Work} = \text{force} \times \text{distance}$$

For example, if a 20 N force is applied to a box that slides 5 m, then the work done is given by:

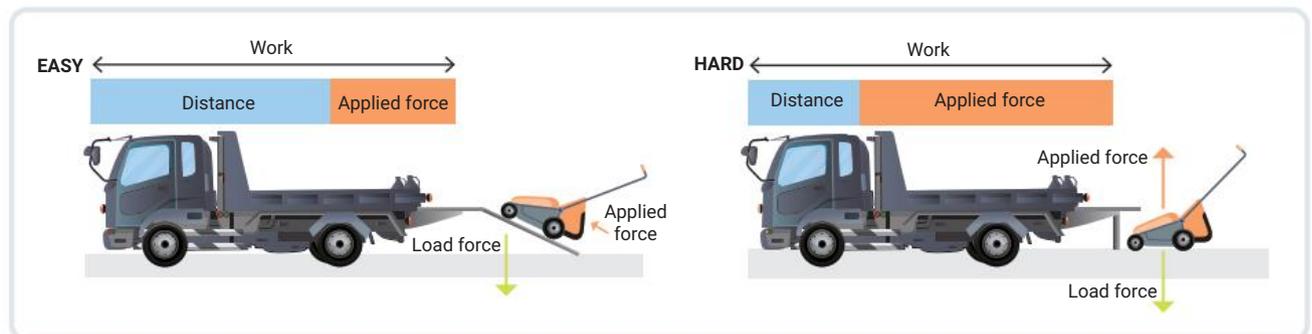
$$20 \text{ N} \times 5 \text{ m} = 100 \text{ J}$$

It is important to note that the same amount of work needs to be done to lift the heavy object into the truck no matter the path that we take.

For example, we could move the heavy object up a smooth ramp instead of lifting it straight up. Since the amount of work remains the same, if the distance travelled is doubled, the force needed is halved. Therefore, it is much easier to get the heavy object into the truck (Figure 5.11.2).

The amount by which a simple machine increases the size of the applied force is known as the machine's **mechanical advantage**. In this case, the mechanical advantage is 2 because without the machine, the force needed to complete the job is twice the force needed with it.

mechanical advantage
a measure of the force multiplication provided by a machine



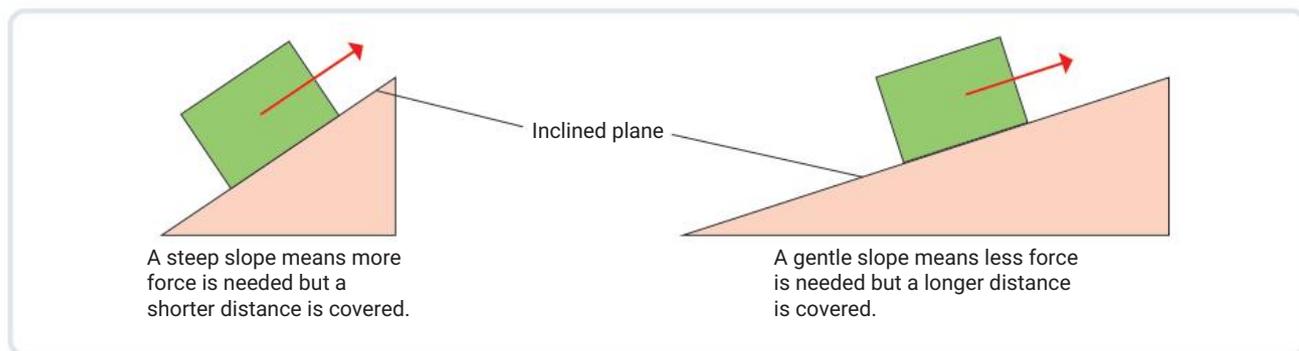
▲ FIGURE 5.11.2 A smaller applied force over a greater distance does the same amount of work as a greater applied force over a shorter distance.

Types of simple machines

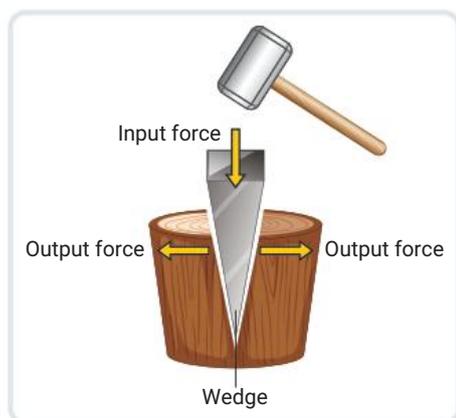
Inclined plane

An inclined plane is an even surface at an angle; for example, a ramp used for wheelchair access to a building.

The amount of work required to move an object is unchanged, but an inclined plane enables a smaller force to be applied to move an object vertically even though it is over a longer distance. The longer the inclined plane, the less steep it is and the greater the mechanical advantage (Figure 5.11.3). Therefore, less force will be required to move an object up it but the distance the object needs to be moved will increase.



▲ FIGURE 5.11.3 An inclined plane gives the greatest mechanical advantage if it is long and less steep.



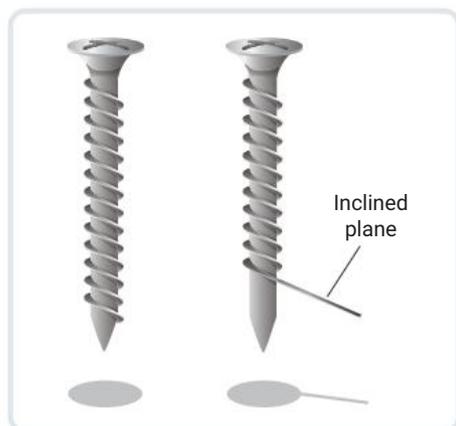
▲ FIGURE 5.11.4 A wedge such as this multiplies the force and changes the direction of the force. Here, the sledgehammer pushes the wedge downwards, and the wedge pushes the wood outwards, causing the wood to split.

Wedge

A wedge is a solid triangular object tapering towards one edge. A wedge is like a moving inclined plane that can be driven between two objects to exert a force that separates them. For example, the blade of an axe is a wedge.

The amount of work required is unchanged – a wedge might need to be moved a long way to achieve a small lift, but the force required will be less than that needed to move the object without a wedge. The further the wedge moves to achieve a move, the greater the mechanical advantage.

A wedge also changes the direction of the force. When a wedge is pushed forwards between a heavy object and the floor, the object is forced upwards. When a wedge is pushed downwards into a log (as seen in Figure 5.11.4), the pieces of wood are pushed sideways away from each other. The narrower the wedge, the greater the mechanical advantage.



▲ FIGURE 5.11.5 A screw consists of an inclined plane wrapped around a cylindrical shaft.

Screw

A screw is a long, inclined plane wrapped around a solid cylinder (Figure 5.11.5). Therefore, the way a screw works is similar to the inclined plane. An example of a screw is a car jack, which is used as a simple machine. The amount of work required is unchanged – each turn of the screw moves the top of the jack a small distance. However, the force is applied over a larger distance as the screw is turned, so the force needed is less. This is evidence of the mechanical advantage of the screw. A winding road up a mountain has features in common with a screw.

Wheel and axle

If a large wheel is connected to a small axle, when the wheel is turned, the axle will also turn (Figure 5.11.6). An example of a wheel and axle is a bathroom tap.

As with other simple machines, a smaller force needs to be applied over a greater distance. The outside of the wheel will move a larger distance in a circular arc than the small distance moved by the outside of the axle. The amount of work required is unchanged. Another way of looking at this is that the turning force that the axle can apply is greater than the turning force needed to turn the wheel. This is the mechanical advantage of the wheel and axle system. The bigger the radius of the wheel compared with the axle, the greater the mechanical advantage. Trucks and buses have very large steering wheels to use the mechanical advantage offered by this simple machine.

Pulley

A pulley is an arrangement of a wheel that can turn on an axis and can be used to change the direction of and/or multiply a tension force in a rope or string (Figure 5.11.7). For example, a pulley can be used to raise a heavy bucket from a well.

The more pulleys that are used in combination, the greater the mechanical advantage. This means that a smaller applied force can give the required force, although the amount of work required is unchanged. The distance the rope must be pulled will increase by the same value as the mechanical advantage. For example, imagine you have to move an object 2 metres. It takes 150 N to move the object and you have a pulley system that gives a mechanical advantage of 3. In this case, only 50 N is needed to move the object, but the 50 N force must be applied over 6 metres. The calculation is as follows.

$$\begin{aligned}\text{Work} &= \text{force} \times \text{distance} \\ &= 150 \text{ N} \times 2 \text{ m} \\ &= 300 \text{ J}\end{aligned}$$

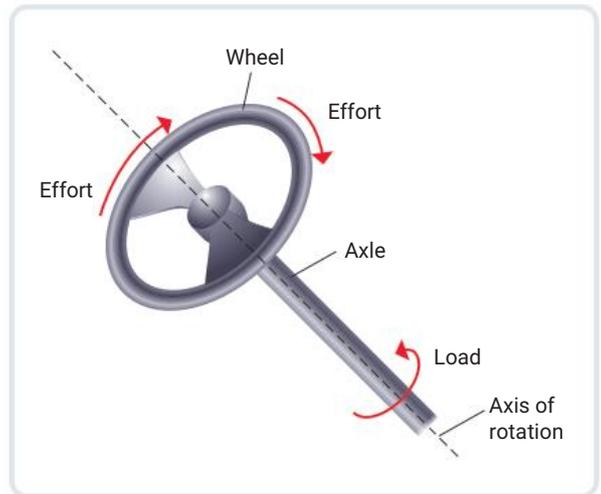
$$\text{Mechanical advantage} = 3$$

$$\text{Force required is reduced to } \frac{150}{3} = 50 \text{ N}$$

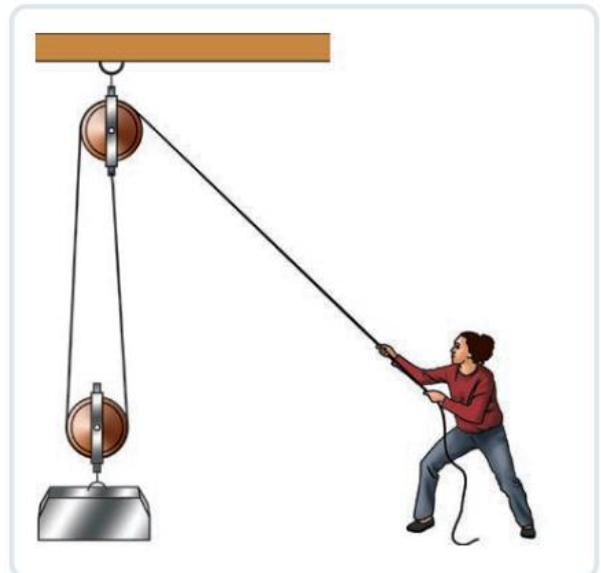
$$\text{Same amount of work, therefore work} = 300 \text{ J}$$

$$300 \text{ J} = 50 \text{ N} \times \text{distance}$$

$$\text{Therefore, distance} = \frac{300}{50} = 6 \text{ m}$$



▲ FIGURE 5.11.6 A wheel and axle multiplies force and changes the position of the force.



▲ FIGURE 5.11.7 A pulley multiplies force and changes the direction of the force.

fulcrum
the point at which a lever is supported and rotates

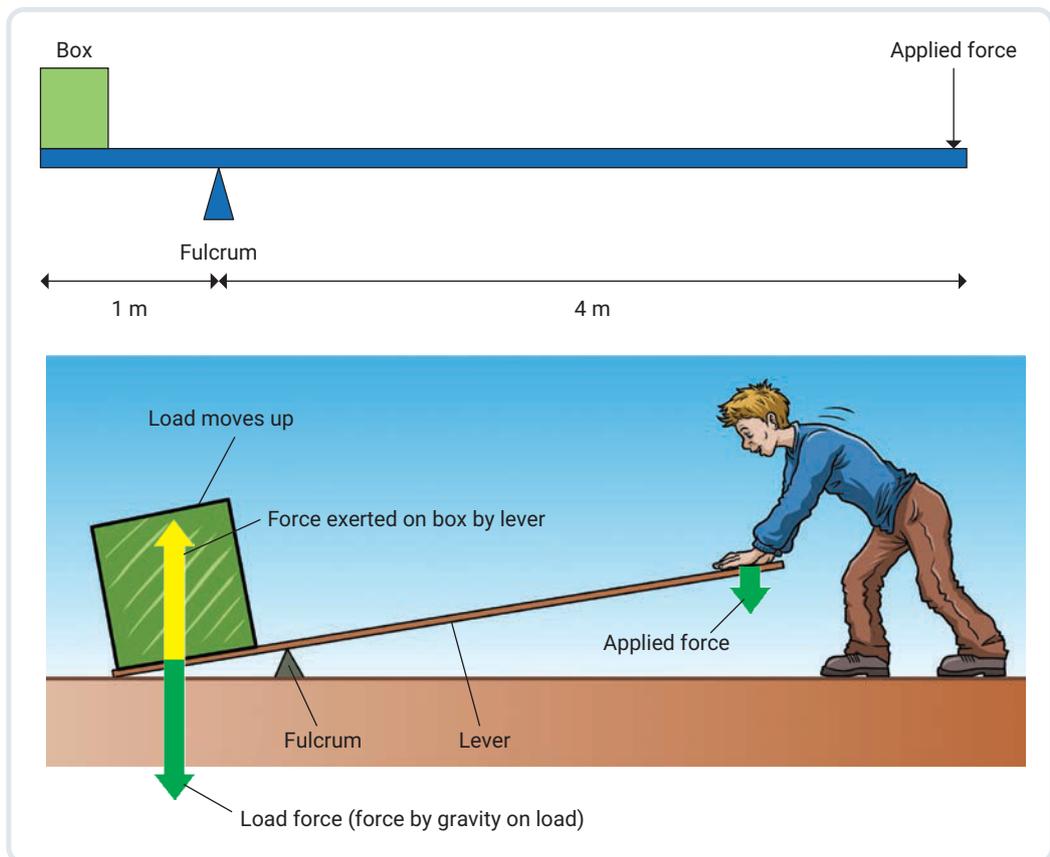
Lever

A lever is a solid, straight object, like a piece of wood or a metal bar, that rotates about a point called a **fulcrum**. A seesaw, a spoon being used to remove a tight lid from a food tin, and a screwdriver being used to remove the lid of a paint can are examples of levers.

A small force applied at a large distance from the fulcrum results in a large force acting at a small distance from the fulcrum. The bigger the distance from the applied force to the fulcrum compared with the distance from the load to the fulcrum, the greater the mechanical advantage.

The amount of work required is unchanged, but a smaller force applied over a longer distance results in a larger force applied over a smaller distance.

For example, the lever in Figure 5.11.8 has a mechanical advantage of 4. So, if a 100 N force is required to lift the box directly, then the applied force on the lever needs only to be 25 N. However, if the box needs to be lifted 30 cm, then the applied force would need to be applied over a distance of 4×30 cm (120 cm) to lift the box the required distance.



▲ FIGURE 5.11.8 A lever multiplies force and changes the position and direction of the force.

5.11 LEARNING CHECK

- 1 **Describe** the main function of a simple machine.
- 2 If you have tried to ride a bicycle up a steep hill, you might have zigzagged across the width of the road and back to make it easier. **Compare** this process with using a screw, a ramp, a wheelbarrow or a pair of pliers.
- 3 **State** what is meant by mechanical advantage.
- 4 Copy and complete the following table by placing an 'x' in the appropriate column to identify what type of simple machine each device is.

Machine/device	Inclined plane	Wedge	Screw	Wheel and axle	Pulley	Lever
Axe						
Bottle opener						
Car jack						
Cheese grater						
Crowbar						
Door hinge						
Doorknob						
Drill						
Flag-raising device on a flagpole						
Jar lid						
Ladder						
Pliers						
Screwdriver						
Shovel						
Tweezers						
Wheelbarrow						

- 5 Research Archimedes' screw and write a paragraph to **explain** how it works and what it is used for.
- 6 A boulder with a mass of 120 kg needs to be lifted from the ground.
 - a **Calculate** the weight of the boulder.
 - b **Calculate** the force needed to lift the boulder with a lever that has a mechanical advantage of 15.
 - c Challenge: If the end of the lever is pushed down 1208.9cm, how far will the boulder be lifted? (Hint: Calculate the work done to push the lever down and use this to calculate the distance the boulder moved.)



Making predictions using cause-and-effect relationships

SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THIS SKILL:

- ▶ using cause-and-effect relationships to make predictions.

You learned in Chapter 1 that a cause-and-effect relationship is when one action (the cause) affects another thing or event, resulting in a change (the effect). In science, we investigate cause-and-effect relationships by following the scientific processes and conducting fair tests. We do this by observing how the variable we are changing (the independent variable) affects the variable we are measuring (the dependent variable).

We can use cause-and-effect relationships and models to make predictions.

Here are some important points to consider when making predictions using cause-and-effect relationships.

- **Observe the cause-and-effect relationship** – some cause-and-effect relationships are easy to observe and identify, such as pushing a toy car to make it move. Observing the relationship makes it easier to understand, which helps you make predictions.

- **Model the cause-and-effect relationship** – some relationships may best be studied using a model. For example, it's easier to understand how Earth's tilt causes the seasons if you use a physical model. In these cases, modelling the cause-and-effect relationship helps you understand it and make predictions.
- **Use good quality data** – your predictions will be better if you have good data, so make sure you control the variables to ensure the test is fair.
- **Use lots of data** – repeat the steps in your investigation by conducting multiple trials. This will give you more data to make good predictions. You can also use secondary data to make predictions.

In the following investigation, you will make predictions about the cause-and-effect relationship between applied force and the distance from the fulcrum in a lever.

INVESTIGATING LEVERS AS SIMPLE MACHINES

BACKGROUND INFORMATION

We can use a ruler and a boss head to make a lever. In this experimental set-up (Figure 5.12.1), the force of gravity is acting on the weights on one side of the lever. We will balance the lever by adding weights to the other side.

AIM

To investigate the relationship between the force applied and the distance from the fulcrum when a lever is acting as a simple machine

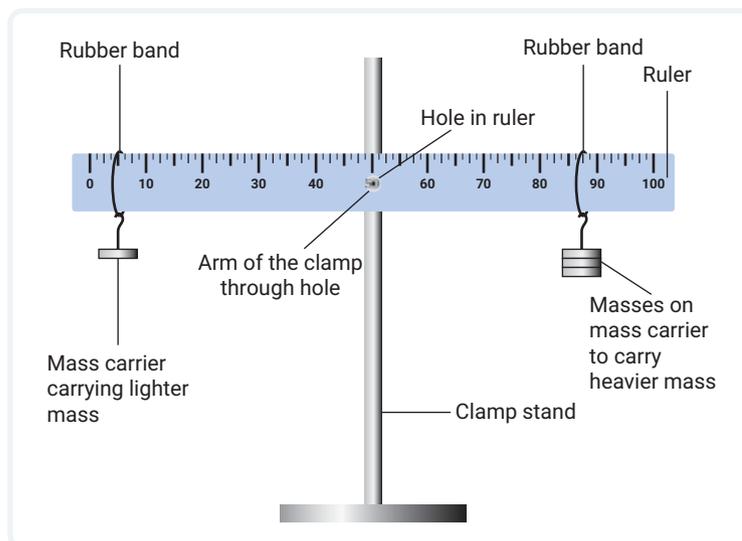
MATERIALS AND EQUIPMENT

- ✓ 1-metre ruler with a hole drilled through the centre at the 50 cm mark

- ✓ clamp stand
- ✓ boss head
- ✓ clamp and arm
- ✓ 2 rubber bands
- ✓ 2 mass carriers
- ✓ 3 × 50 g masses

PROCEDURE

- 1 Predict what distance the weight on the right-hand side needs to be from the centre of the ruler to keep the ruler level as weights are added to it. Your prediction could take the form 'As more weights are added to the right side, to keep the ruler level the weights need to be moved ...'
- 2 Set the clamp in the boss head on the clamp stand so that the arm of the clamp is parallel to the desk-top (Figure 5.12.1).



▲ FIGURE 5.12.1 The experimental set-up

- Place the metre ruler so that the arm passes through the hole in the middle of the ruler and the ruler can rotate on the arm.
- Suspend one mass carrier from one of the rubber bands at the 0.050 m (5 cm) mark at the left end of the ruler. Be careful to hold the ruler in place so it doesn't swing and hit someone.
- Suspend the other mass carrier from a rubber band and move it into a position on the right side of the ruler so that it balances with the left-hand weight. Record the distance of the right-hand mass carrier from the centre in the table below.
- Add one 50 g mass to the right-hand mass carrier, and move it along the ruler until the lever is balanced.
- Measure this distance and record the value in the table below.
- Repeat steps 5 and 6 with two 50 g masses and then with three 50 g masses.
- Calculate the values in the last column of the table using the formula shown.

RESULTS

Record your data in the following table. Remember to convert your units from cm into m, and from kilograms into grams.

Total mass (m) on right (kg)	Distance (d) of mass from centre (m)	Force \times distance for lever ($m \times 9.8 \times d$)
0.050		
0.100		
0.150		
0.200		

ANALYSIS

- What do you notice about the values of $m \times 9.8 \times d$ in the results table above?
- How do these values compare to the value of $m \times 9.8 \times d$ calculated for the left side of the lever?
- Predict how much mass you need to apply 10 cm (0.1 m) from the fulcrum to balance the lever.
- Do these results match your predictions about the relationship between force and distance in levers?
- What were some of the challenges of this experiment? How do you think these challenges affected your results?

CONCLUSION

Write a short conclusion. Remember to state if the data you collected supports your prediction.

5.13 Spear-throwing technology

**IN THIS MODULE
YOU WILL:**

- ✓ investigate the use of forces in spear-throwers developed or used by Aboriginal and Torres Strait Islander Peoples

Joe Sambono



▲ **FIGURE 5.13.1** Spear-throwers are carefully constructed, and different cultural groups use different designs. Origin from top to bottom: Central Desert Region, Northern Territory; Cape York, Queensland; Port Keats, Northern Territory.

Examining spear-throwers

Aboriginal and Torres Strait Islander Peoples developed and produced a range of tools designed to increase both the speed and accuracy of hunting projectiles, such as spears and arrows. Across much of Australia, many Aboriginal and Torres Strait Islander Peoples developed, used or refined spear-throwers. Peoples of the Torres Strait used bows and arrows as well as spear-throwers.

There is evidence that Aboriginal Peoples began to manufacture and use spear-throwers at least 5000 years

ago and that the development of this hunting technology is similar to that of other First Nations Peoples of the world.

Spear-thrower technology highlights Aboriginal and Torres Strait Islander Peoples' understanding of forces and levers. A spear-thrower helps hunters throw further by acting as an extension of the thrower's arm. A longer 'arm' (or longer lever) means that more force can be put behind the spear and it can go faster and further.

Spear-throwers are crafted out of wood, usually hardwood such as mulga. However, the shape, width and length vary depending on the cultural group's design (Figure 5.13.1) and the environment in which it was used. Each spear-thrower needs to be carefully constructed for its individual user to maximise its effect when used.

Spear-throwers typically narrow towards the gripping end where notches coated in resin are cut into either side to form a hand grip (Figure 5.13.2a). The other end has a 'peg' (Figure 5.13.2b), often made from a different material, that fits into a socket or notch at the base of the spear.

Joe Sambono



Joe Sambono



◀ **FIGURE 5.13.2** (a) Spear-throwers are used to increase the distance, speed and accuracy of spears. This spear-thrower is from Galiwinku, Northern Territory. (b) The peg at the base of the spear.

☆ ACTIVITY

- 1 Draw** a labelled force diagram to show the forces acting on a spear:
 - a when it is resting in the spear-thrower (before being thrown).
 - b in motion through the air after being thrown.
- 2** For the diagrams you drew in Question 1, **explain** if the forces are balanced or unbalanced.
- 3 Describe** what advantages the spear-throwers give to the hunters.
- 4 Explain** how the spear-throwers give these advantages. (Hint: Spear-throwers are levers.)

5.14 Earth's magnetic field

BY THE END OF
THIS MODULE, YOU
WILL BE ABLE TO:

- ✓ describe Earth's magnetic field and why it exists
- ✓ explain the role that Earth's magnetic field plays in the survival of living things on Earth.

Earth's magnetic field

Earth is surrounded by an immense magnetic field (Figure 5.14.1). This makes Earth act like a giant magnet. The magnetic field extends thousands of kilometres into space. Earth is the only rocky planet in our solar system to have a magnetic field.

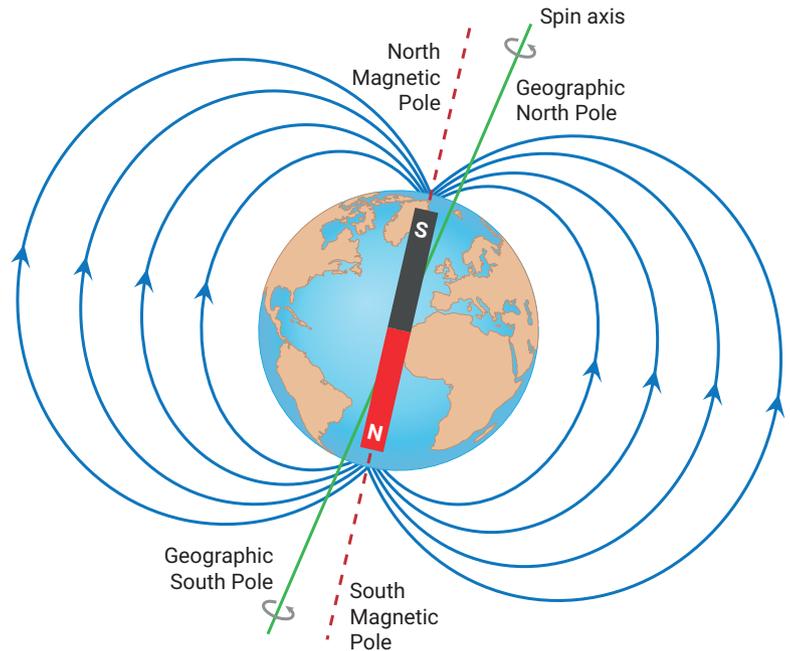
Origin of Earth's magnetic field

To understand the origin of the magnetic field, we need to explore the four layers of Earth from the outside towards the centre (Figure 5.14.2):

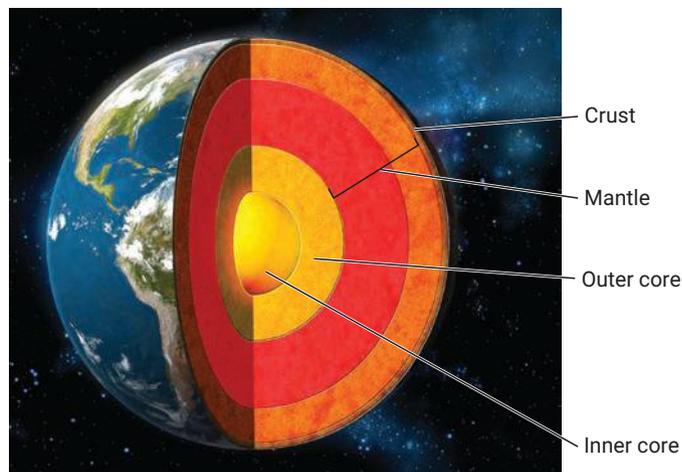
- the crust – the solid layer we live on
- the mantle – mostly solid rock
- the outer core – liquid iron and nickel (types of metal)
- the inner core – solid sphere of iron and nickel.

The movement of the liquid metal in Earth's outer core creates the magnetic field. At Earth's surface, the magnetic field forms two magnetic poles. A series of magnetic field lines join these two poles, which run roughly parallel to Earth's surface.

You will learn more about the layers of Earth in Chapter 17.



▲ FIGURE 5.14.1 Earth's magnetic field acts like a large magnet. Notice that the geographic poles indicated by the green line are not in the same locations as the magnetic poles.



▲ FIGURE 5.14.2 The four layers of Earth

Location of the magnetic poles

The magnetic poles are the places on Earth where the magnetic field points straight down. As you can see in Figure 5.14.1, Earth's geographical North Pole and North Magnetic Pole are close together, but not exactly the same. Currently, the distance between them is about 400 km. The locations of the magnetic poles are not fixed, and the direction of the magnetic poles sometimes reverses! The last time this occurred was around 780 000 years ago.

Importance of the magnetic field

The magnetic field shields Earth from harmful radiation and particles emitted by the Sun and other objects in space. Without the magnetic field, high radiation would cause problems such as satellites and electrical power not working, and even the destruction of Earth's atmosphere.

Auroras result from the magnetic field

Auroras are dynamic patterns of brilliant, coloured lights that appear as curtains, rays, spirals or flickers (Figure 5.14.3). They are often called the northern lights and the southern lights. You can see them in the night sky at latitudes close to the magnetic North and South Poles.

These spectacular events are caused by charged particles from the Sun, moving at high speed through space. When the particles enter Earth's magnetic field, they **deflect** towards the magnetic poles where they hit the atmosphere. This collision results in the patterns and colours we see.

deflect

experience a change in direction due to a force



▲ FIGURE 5.14.3 An aurora seen from Tasmania

Animals using magnetic fields

Many types of living things, including bacteria, algae, honeybees, birds, stingrays, dolphins and whales, can detect and use magnetic fields to **orientate** themselves. Living things have different mechanisms that allow them to do this, many of which scientists are still investigating. For example, scientists know that some species of sea turtle **navigate** by detecting differences within a magnetic field, allowing them to use the field as a map. But scientists don't yet understand exactly how they do this.

orientate

align with or direct towards

navigate

find the way; travel in the correct direction

How to make a simple compass

Aim

To make a simple compass that aligns to Earth's magnetic field

Materials and equipment

- paperclip or needle
- magnet
- cork or foam
- thread
- icy-pole stick
- large jar

Procedure

- 1 Straighten the paperclip into a wire.
- 2 Wipe one pole of a magnet along the paperclip or needle a few times. It will now be magnetised.
- 3 Tie one end of a piece of thread in the middle of the paperclip or needle. Tie the other end to an icy-pole stick.
- 4 Suspend the paperclip or needle by the stick over the neck of a large enough jar to allow it to clear the sides (Figure 5.14.4). Alternatively, you can push the paperclip or needle through a piece of cork or foam and then float it on water in the jar.
- 5 You should observe the paperclip or needle aligning itself with the magnetic field.

☆ ACTIVITY

Hanging compass



Floating compass



▲ FIGURE 5.14.4
Simple compass designs

5.14 LEARNING CHECK

- 1 **Describe** the shape of Earth's magnetic field.
- 2 **Discuss** the importance of Earth's magnetic field to life on Earth.
- 3 **Explain** why you see auroras close to Earth's magnetic poles.
- 4 Why is it important to move away from metal objects when using a compass?

5 REVIEW

REMEMBERING

- 1 List** the three indirect forces.
- 2 State** the general name given to forces that act along a string or rope or cable.
- 3 State** the name of the force that is acting on the Moon as it orbits Earth.
- 4 Define** 'net force'.
- 5 Identify** the statements below as true or false.
 - a** Stationary objects have no forces acting on them.
 - b** A force is an interaction between objects.
 - c** Both mass and weight would change if an object was moved from Earth to the Moon.
 - d** Force is measured in kilograms.
 - e** There are always two forces acting on any object – the applied force and the reaction force.
 - f** The more mass an object has, the harder it is to change its motion.

UNDERSTANDING

- 6 Justify** why skiers and speedskaters in the Winter Olympics wear shiny, smooth suits and helmets and tuck down as they move.



- 7 Describe** the effects of an unbalanced force.
- 8 Describe** how you presume oil reduces the friction between two surfaces.
- 9 Identify** a situation in which an object could have no weight.
- 10 Explain** how a spring balance measures force.
- 11 Explain** how the mass of a spear affects the distance it travels when a spear-thrower is used.

APPLYING

- 12** At high altitudes, such as near mountain tops, there is less air. When long-jump and cycling competitions take place at high altitudes, world records are often set. **Explain** why this is the case, using the ideas you have learned about friction.
- 13 Predict** what would happen if you tried to jump while on the Moon.
- 14 Compare** the force exerted by a magnetic north pole on another north pole with the force exerted by the Sun on Earth.
- 15 Describe** a situation that happened today in which you have relied on friction to complete a task.
- 16 Predict** what would happen if you increased the length of a lever while keeping everything else the same.
- 17 Explain** how you could increase friction between your feet and the ground when walking.
- 18 Classify** the following situations as having balanced forces or unbalanced forces.

- a** A kite motionless in the air
- b** A leaf falling at a steady rate
- c** A ball going over the fence and landing in the neighbour's pool
- d** The ball floating in the neighbour's pool
- e** An elevator moving up ten floors, going past one floor of a building every 3 seconds
- f** A cyclist going around a corner
- g** A snowboarder slowing down at the end of a run
- h** A weights bar held above a weightlifter's head



- 19 You need to move a heavy box of books across the room. Without using any simple machines, **describe** three changes you could make so that the box will cross the room in less time.



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- 20 **Describe** a situation around the house or school in which a pulley is used.
- 21 A tennis ball falls towards the ground. **Draw** a diagram with force arrows to show the direct force and indirect force that act on the ball, clearly indicating which force is larger.

EVALUATING

- 22 **Explain** why it is easier to move an object up a set height by using a long ramp than by using a short ramp.
- 23 **Predict** the changes to the weight of a lunar rover when it is transported from the surface of Earth to the surface of the Moon.
- 24 **Apply** your knowledge of forces and simple machines to explain why less force is needed to turn a screwdriver with a wide handle than one with a narrow handle.



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- 25 **Predict** what difference you would notice when driving two identical screws into the same piece of wood if one has five turns per centimetre and the other has 10 turns per centimetre. Justify your prediction.
- 26 **Evaluate** the statement attributed to Archimedes: 'Give me a lever long enough and a fulcrum on which to place it and I shall move the world'.
- 27 Consider the simple machines described in this chapter. Which do you think has affected our lives the most? **Justify** your choice.

CREATING

- 28 **Sketch** a horse pulling a sled along the ground. Annotate the diagram with all the direct and indirect forces acting on the horse, the sled and the ground.



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SCIENCE IN DEPTH STUDY

#5

1 Connect what you've learned

In this chapter, you've learned about forces and how they do or do not change the way an object moves.

Draw a mind map to show the types of forces and the circumstances when forces cause motion to change, or not change. Use the key words from each module to prompt you.

2 Check your thinking

At the start of the chapter, you were asked the following questions.

- How could an object so huge be moved by people without sophisticated machinery?
- How can we use a knowledge of forces to overcome the challenge to lift and move heavy objects over a distance?

Use the knowledge gained in this chapter to explain the forces that need to be overcome to lift and move heavy objects. Describe how this can be done with simple machines.

3 Get into action

Research how scientists believe the Easter Island stones, and other ancient heavy statues and objects (including Stonehenge, Angkor Wat and the pyramids), were moved by people without sophisticated machinery. Where can you see the principles that you have learned about forces and simple machines represented in your research?

4 Communicate

Make a picture book or presentation that could be used to teach a Year 5 or 6 class about forces.



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CELLS AND CLASSIFICATION

SYLLABUS OUTCOMES

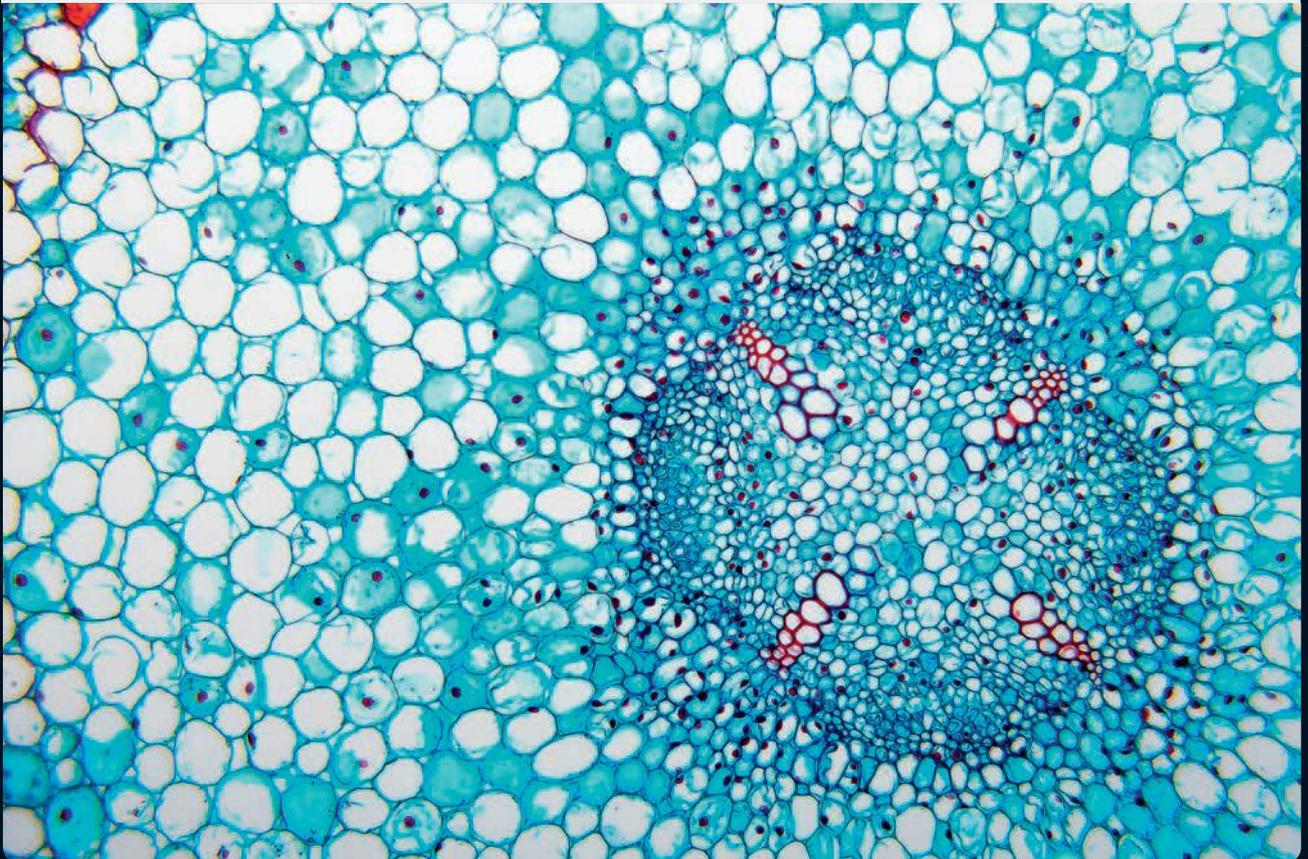
A STUDENT:

- ▶ describes the unique features of cells in living things and how structural features can be used to classify organisms SC4-CLS-01
- ▶ uses scientific tools and instruments for observations SC4-WS-01
- ▶ follows a planned procedure to undertake safe and valid investigations SC4-WS-04
- ▶ communicates scientific concepts and ideas using a range of communication forms SC4-WS-08

CHAPTERS RELATED TO THIS FOCUS AREA ARE:

- ▶ **CHAPTER 6** – CLASSIFYING LIVING THINGS
- ▶ **CHAPTER 7** – CELLS

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6

Classifying living things

6.1 Classification (p. 214)

Classification is organising objects into groups based on similarities.

6.2 Dichotomous keys (p. 216)

A dichotomous key is a sequence of steps that divides groups into two to identify an object or a living thing.

6.4 Classifying living and non-living things (p. 223)

You can classify the things in the world around you into two broad groups: living things and non-living things.

6.3 WORKING SCIENTIFICALLY: Creating a dichotomous key (p. 219)

Dichotomous key for science equipment

6.5 Different species (p. 225)

Species are organisms with similar characteristics that produce fertile offspring.

6.6 WORKING SCIENTIFICALLY: Classifying Australian animals (p. 228)

Constructing an Australian animal dichotomous key

6.8 Linnaean classification of living things (p. 233)

Linnaean classification organises living things into groups that progressively become more specialised.

6.7 Adaptations of Australian species (p. 230)

Adaptations allow organisms to survive and reproduce in their local environment.

6.9 The kingdoms of living things (p. 238)

All living things belong to one of five kingdoms.

6.10 Naming living things (p. 242)

Living things are named by their genus and species.

6.12 SCIENCE IN CONTEXT: Changing classifications (p. 248)

Classifications may change as new information becomes available.

6.11 ABORIGINAL AND TORRES STRAIT ISLANDER SCIENCE CONTEXTS: Classification systems (p. 246)

Aboriginal and Torres Strait Islander Peoples have developed classification systems for plants and animals.



▲ FIGURE 6.01 Observe these organisms. How can they be grouped?

- ▶ What do the organisms in Figure 6.0.1 have in common?
- ▶ What are the main characteristics of each organism?
- ▶ How can they be organised into groups?
- ▶ How are they named?

#6 DIVE INTO SCIENCE!

At the end of this chapter, you can complete Science in Depth Study #6. You can use the information you learn in this chapter to complete the project.

Assessments

- Prior knowledge quiz
- Chapter review questions
- End-of-chapter test
- Depth study: Dichotomous key

Videos

- Science skills in a minute: Dichotomous keys (6.3)
- Video activities: Dichotomous keys (6.2); How Australian animals adapt (6.7); Carl Linnaeus' classification system (6.8); Naming species (6.10); What is taxonomy? (6.12)

Science skills resources

- Science skills in practice: Creating a dichotomous key (6.3)
- Extra science investigations: Identifying insects (6.10)

Interactive resources

- Drag and drop: Get classifying! (6.1); What is a species? (6.5)
- Label: Levels of classification (6.8)
- Match: Kingdoms (6.9)
- Quiz: Kingdoms (6.9)

6.1 Classification

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define classification and characteristic
- ✓ describe examples of classification
- ✓ classify objects based on similar characteristics
- ✓ explain the reason for classifying objects.



Interactive resource
Drag and drop: Get classifying!

classification

grouping things according to how similar they are

characteristic

a quality or feature that makes something recognisable

GET THINKING

When you go grocery shopping with your parents, where would you find the following?

- Ice-cream
- Bread
- Washing powder
- Apples
- Frozen pizza
- Cheese
- Wraps
- Dog food
- Yoghurt
- Tomatoes
- Cleaning products
- Cat food
- Bananas

Reflect on your answers. Why is each of the items found in that location? What would happen if they were somewhere else? What other places are organised in a certain way? Why do they do this?

Understanding classification

Classification is the process of organising things into groups based on similar **characteristics**. Organising things into groups based on their similar characteristics provides information about members of the group. For example, at school you are organised into year groups based on age. This means that your teachers know what you have already learned and what you need to learn during the year. In sporting teams, you may be organised into different divisions based on previous successes. This helps your coach know the ability of the team and means that you are playing against other teams of a similar ability. In a zoo, the animals are organised according to their native environments. This helps their keepers provide a suitable habitat and allows visitors to understand where the animals came from.



▲ FIGURE 6.11 Zoos have a nocturnal house for animals that are active at night, such as this ringtail possum at Sydney Zoo.

To be effective, a classification system must use the right kinds of characteristics. Each characteristic should be:

- observable so that it can be easily identified
- consistent so that the object will always be classified in the same way
- related to the reason for classification so that the information is valid.

There are many reasons for classifying things, and the reason will determine the way that they are classified. For example, food may be classified as:

- savoury or sweet
- containing gluten or gluten-free
- eaten when hot, cold or at room temperature
- fresh or processed
- cereal, dairy, fruit and vegetable or meat.



▲ FIGURE 6.1.2 One way of classifying food is as savoury or sweet.

6.1 LEARNING CHECK

- 1 **Define** classification.
- 2 What characteristics would you use to help a person identify vanilla ice-cream who has never eaten it? Choose all options that apply.
 - a It is sweet.
 - b It is served on a plate.
 - c It is eaten cold.
 - d It smells and tastes like vanilla.
- 3 **Describe** how cutlery (knives, forks and spoons) is organised in your kitchen drawer. **Explain** why it is arranged this way.
- 4 Use the photo to **classify** buttons. **State** the characteristics of the buttons that you would use to classify the buttons into:
 - a two groups.
 - b more than two groups.
- 5 **Discuss** the advantages of classifying car drivers into learners (L plates), provisional (P plates) and open (full) licence.



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6.2 Dichotomous keys

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define dichotomous key
- ✓ apply a dichotomous key to identify an object
- ✓ construct simple dichotomous keys.



Video activity
Dichotomous keys

GET THINKING

Like many scientific terms, the word 'dichotomous' comes from Latin and Greek root words. Use the information in Table 6.2.1 to predict what dichotomous means.

▼ TABLE 6.2.1 The meaning of the word 'dichotomous'

Root word	Language	Meaning/use
di-	Greek	two
dicho-	Greek	in two parts
tom-, tomia	Greek	to cut
-ous	Latin	a suffix that makes a word an adjective (describes a noun)

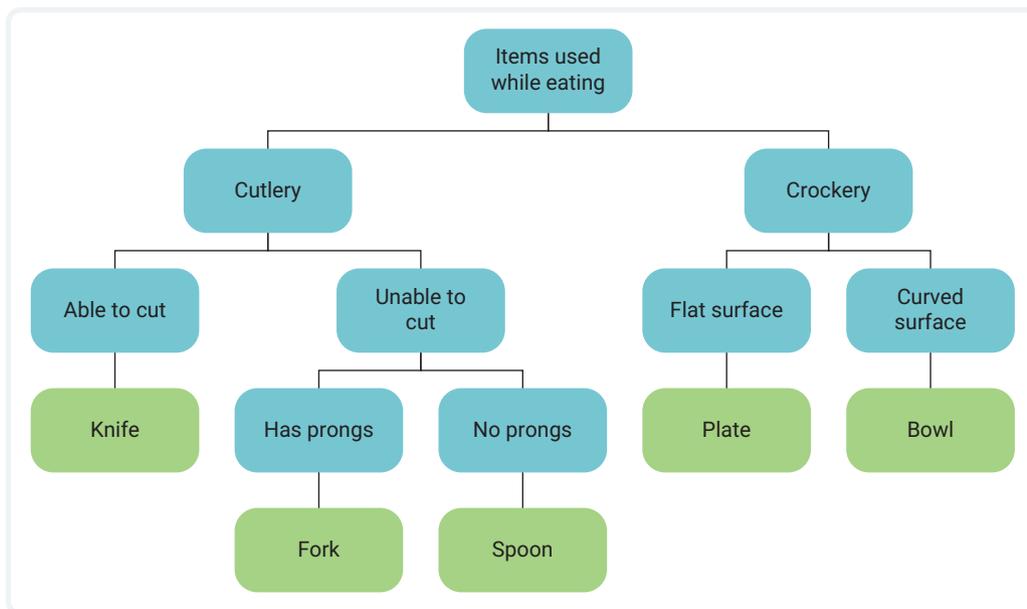
What is a dichotomous key?

dichotomous key

a tool used by scientists to classify objects (often living things); two choices are given at each level, until there is only one type of living thing in each final group

A **dichotomous key** is a tool used to classify objects based on dividing a group into two new groups. Each new group is then further divided into two groups. This process continues until there is only one type of object in the group.

Figure 6.2.1 shows a simple dichotomous key for items used to eat with. The original group included plates, bowls, knives, spoons and forks. These were then divided into two groups based on whether they were cutlery (knives, spoons and forks) or crockery (plates and bowls). Each group was then further divided into two groups based on characteristics. Note how the name of the item is listed when it is the only thing in that group.



▲ FIGURE 6.2.1 A dichotomous key for items used to eat with

As with any classification system, the effectiveness of a dichotomous key relies on the chosen characteristics. The characteristics for each division should:

- remain the same for that object so that it can always be placed in the same group
- have two options so that all items can be placed in one of the two groups
- be **objective** (not **subjective**) so that everyone will place the item in the same group.

Dichotomous keys are represented in different formats. The most common formats are tree diagrams and linked keys.

Tree diagram

A **tree diagram** (or branching tree) shows the dichotomous key in a visual format that has lines representing each division. Figure 6.2.3 is a tree diagram of a dichotomous key for different balls used in sports.

objective

not influenced by personal feelings or opinions

subjective

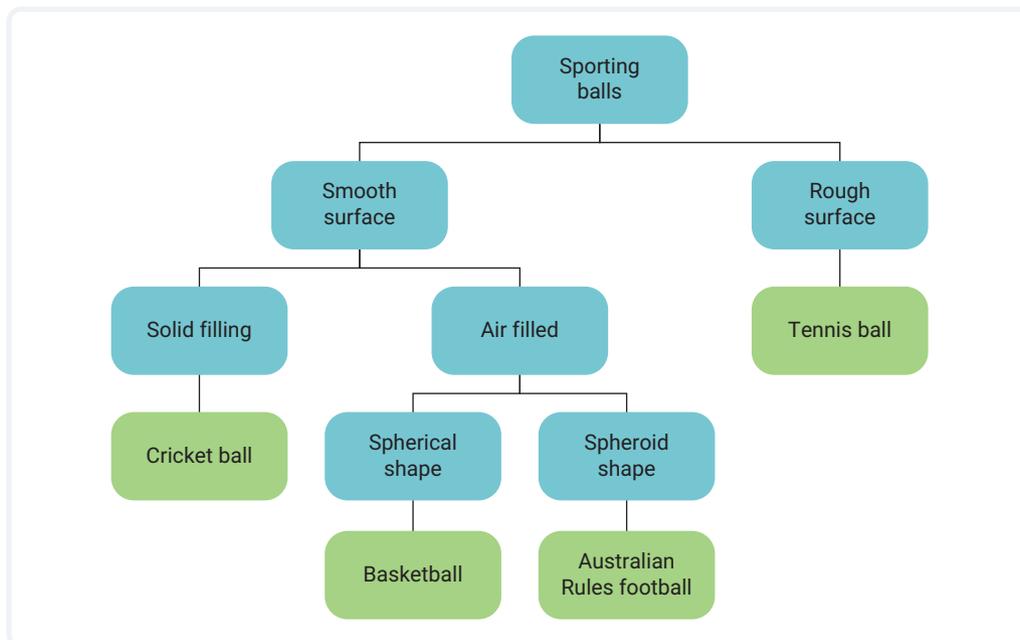
based on personal feelings or opinions

tree diagram

a diagrammatical dichotomous key made by branching, which represents the splitting of each group



▲ FIGURE 6.2.2 Balls used in sports



▲ FIGURE 6.2.3 A tree diagram for a dichotomous key of sporting balls

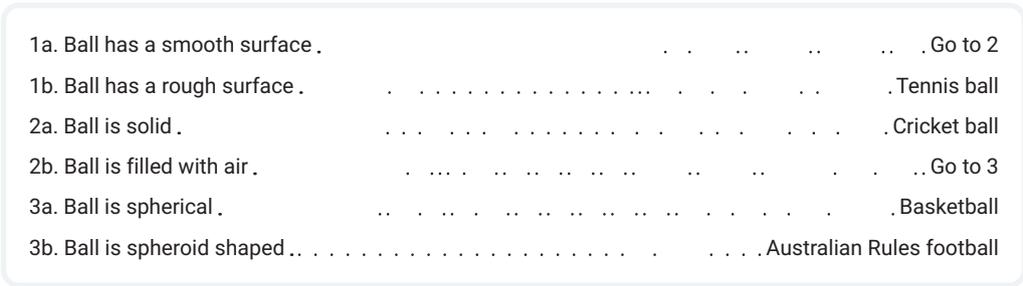
Linked key

A **linked key** (or **tabular key**) is a descriptive key. It is a numbered list of questions, or statements, with two options. The answer to each question directs you to the next question.

linked key (tabular key)

a descriptive dichotomous key made of numbered questions or statements

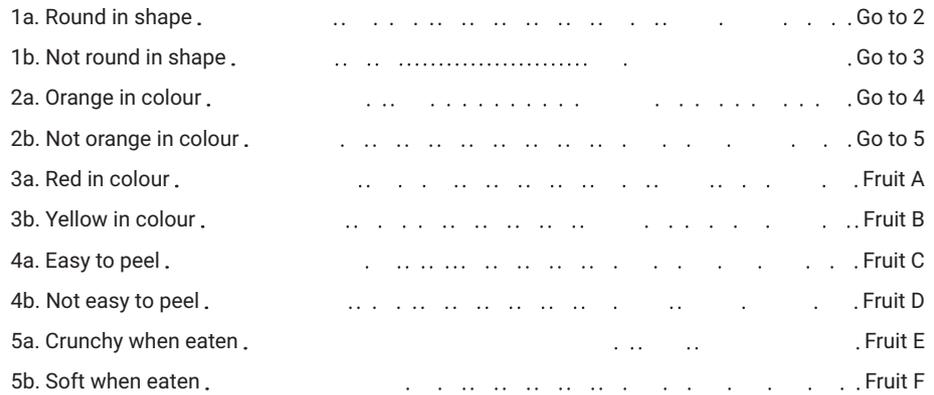
Figure 6.2.4 is a linked key for the dichotomous key for sporting balls.



▲ FIGURE 6.2.4 A linked key for sporting balls

6.2 LEARNING CHECK

- 1 What is a feature of all dichotomous keys?
- 2 Below is a dichotomous key for fruit A–F.



a What letter in the dichotomous key represents each type of fruit listed in the table?

Fruit	Letter
Red apple	
Banana	
Orange	
Plum	
Mandarin	
Strawberry	

- b What type of dichotomous key is this?
- c **Discuss** whether this dichotomous key would be appropriate to identify an apricot.
- d **Discuss** how objective each statement is.

3 **Create** a dichotomous key to identify six items in your pencil case. Represent the dichotomous key in both a tree diagram and a linked key.



SCIENCE SKILLS IN FOCUS

**IN THIS MODULE, YOU WILL FOCUS ON
LEARNING AND IMPROVING THESE SKILLS:**

- ▶ creating a dichotomous key by grouping items based on their characteristics.

Here are some pointers to remember when creating a dichotomous key.

- 1 Dichotomous keys are used to identify objects or living things.
- 2 Before you start making your key, you need to know the properties of the objects that you want to classify. The properties that you use in the dichotomous key should be objective characteristics that do not change. This means that the object is consistently classified in the same way.
- 3 At each step in the key, you need to have two options. No more, no less!
- 4 Each option needs to be written as a statement (a fact), not a question.

For example:

- 3 cm or bigger
- Smaller than 3 cm



Video
Science skills
in a minute:
Dichotomous
keys

**Science skills
resource**
Science skills
in practice:
Creating a
dichotomous key

**DICHOTOMOUS KEY FOR
SCIENCE EQUIPMENT**

AIM

To create a dichotomous key (tree diagram and linked versions) for science equipment

MATERIALS AND EQUIPMENT

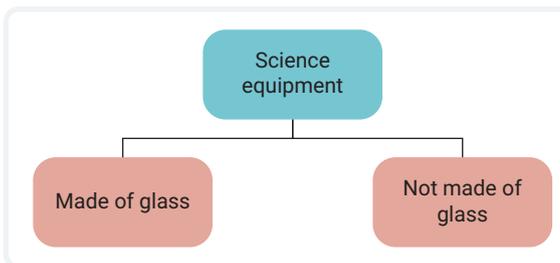
- ☑ pictures of each of the pieces of science equipment shown in Figure 6.3.2. Alternatively, your teacher may make the actual equipment available to you
- ☑ large piece of paper or a whiteboard
- ☑ pens

PROCEDURE

Work in groups of two or three.

**PART A: CREATING A TREE DIAGRAM
FOR A DICHOTOMOUS KEY**

- 1 List the characteristics of each piece of equipment.
- 2 Organise the equipment into two groups based on similar characteristics. Remember to use characteristics that don't change and are not based on subjective opinion.
- 3 Represent this organisation at the start of a tree diagram. An example is shown in Figure 6.3.1.

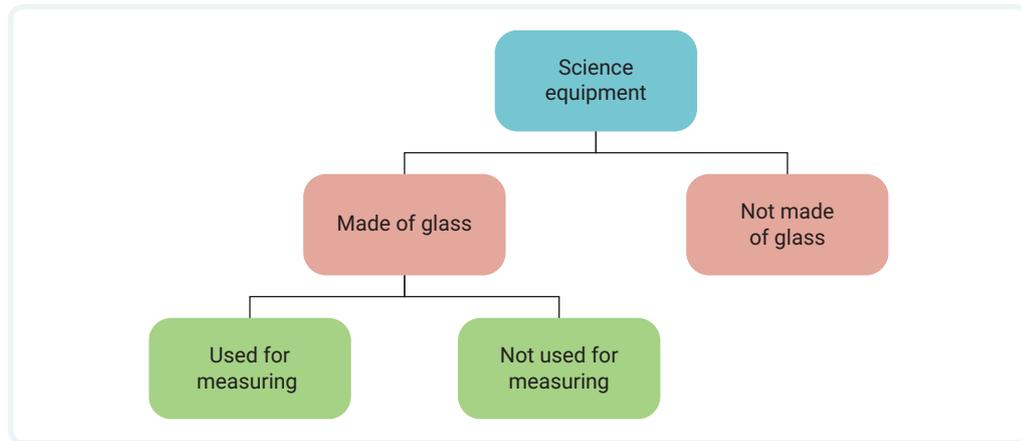


▲ **FIGURE 6.3.1** The start of a dichotomous key for science equipment

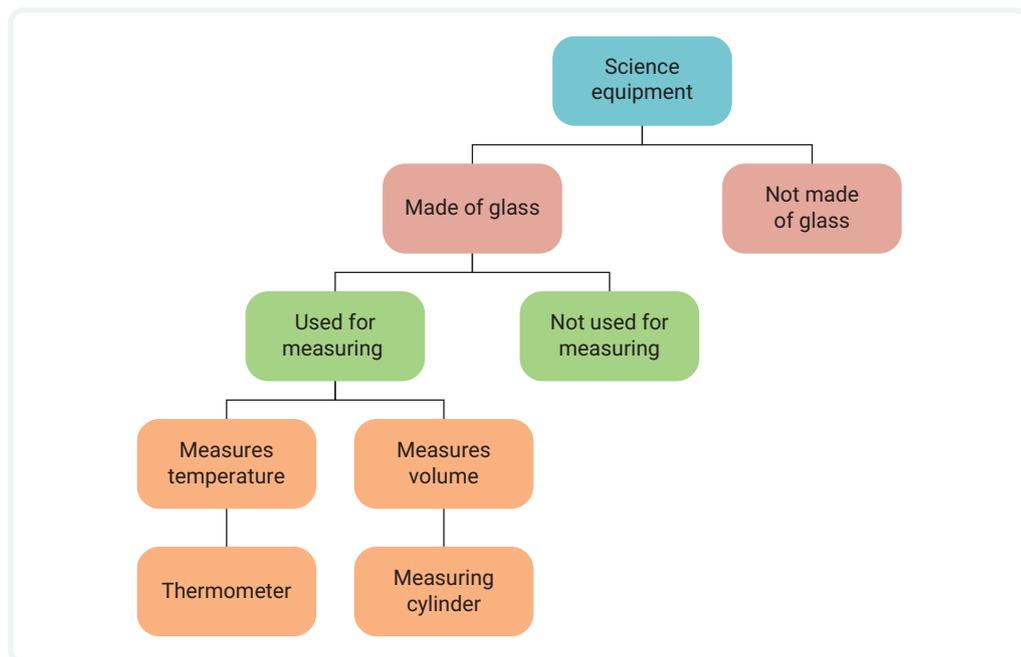
- 4 Choose one of your groups. Divide it into two smaller groups based on similar characteristics.
- 5 Add this organisation to your tree diagram. An example is shown in Figure 6.3.3.
- 6 Repeat steps 4 and 5 until you have only one item in each group. Then, write the name of the item below the characteristic. An example is shown in Figure 6.3.4.



▲ FIGURE 6.3.2 Equipment used in the science laboratory



▲ FIGURE 6.3.3 The continuation of a dichotomous key for science equipment

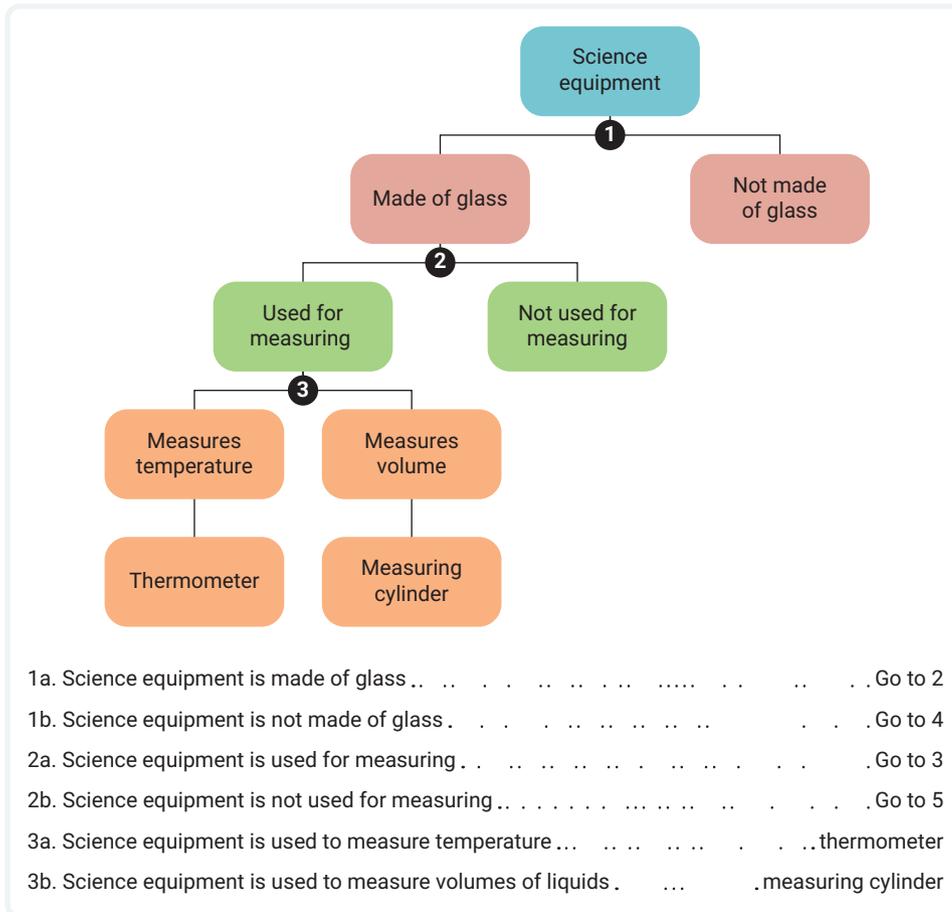


▲ FIGURE 6.3.4 A further continuation of a dichotomous key for science equipment

- 7 Repeat step 6 for each group until there is only one item in every group.

PART B: CREATING A LINKED KEY FOR A DICHOTOMOUS KEY

- Using your tree diagram, write a number at each division of a group. These will become the numbers for your descriptions.
- Start with number 1. Write the description for option a, and the description for option b underneath each other.
- After the description, write what number that option should go to. This is written at the right-hand side of the line. Often a series of dots are used to connect the description and direction. Figure 6.3.5 shows an example.
- Continue this process until you have written the description for each option.



▲ FIGURE 6.3.5 Starting a linked key (tabular key) for a dichotomous key for science equipment

RESULTS

If possible, take a photo of your group’s dichotomous keys.

ANALYSIS

- 1 Were some items hard to classify? What made them hard to classify?
- 2 Do you think you could have done this activity last year? Explain your answer.
- 3 Were the dichotomous keys from other groups the same as yours? Explain your answer.
- 4 If you were to do this activity again, what would you change to make the process more effective?

- 5 What challenges do you think scientists would face when creating dichotomous keys for living organisms?
- 6 Use this process to create a dichotomous key for a range of lollies.

CONCLUSION

Summarise what a dichotomous key is and what you did to create one for science equipment.

6.4 Classifying living and non-living things

6.4

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

✓ list the characteristics of living things.

GET THINKING

When you observe the world around you, you may see many different plants, animals and objects, but how do you categorise or group them? Take two minutes to write a list of the different ways you could group the things you observe in your school's grounds. Share your list with a partner.

Characteristics of living things

You can classify the world around you into two broad groups: 'living things' and 'non-living things'. Scientists use a set of characteristics to distinguish living things from non-living things.

You can remember these characteristics using the mnemonic MRS GREN. Mnemonics are memory aids that can help you remember lists of words or facts.

living things

all organisms that are alive or were alive

non-living things

all the things that were never alive

▼ TABLE 6.4.1 A description of the characteristics of living things, using the mnemonic MRS GREN

Characteristic	Description
Movement	All living things move. Even plants can move their leaves to follow the Sun.
Respiration	All living things gain energy from a process called cellular respiration.
Sensitivity	Living things sense the world around them and respond to stimuli via their senses.
Growth	Living things grow.
Reproduction	Living things reproduce to transfer their characteristics to the next generation.
Excretion	All living things must remove their waste to stay healthy.
Nutrition	Living things need to eat or take in nutrients to survive.

stimuli

things or events that produce a reaction in living things (singular stimulus)

Non-living things

Non-living things are all the objects that were never alive, such as water, rocks, air, the Sun and many everyday objects, such as the pens inside your pencil case and the metal legs of your desk or chair.



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▲ FIGURE 6.4.1 We classify the Sun, air and clouds as non-living things.

Living things interact with and depend on non-living things all the time. For example, seaweed and star fish may completely cover a rock, but this does not make the rock a living thing.



Fuller Photography/Shutterstock.com

▲ FIGURE 6.4.2 We classify rocks as non-living things, even when they are covered in living things.

Why we classify living things

It is important to classify living things because it:

- helps us study and understand life on Earth
- creates a common language to identify and name living things.

6.4 LEARNING CHECK

- 1 **List** the seven characteristics of all living things.
- 2 **Describe** the differences between living and non-living things, using an example.
- 3 Is a fossil a living or non-living thing? **Justify** your answer, using an example.



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6.5 Different species

6.5

BY THE END OF
THIS MODULE, YOU
WILL BE ABLE TO:

- ✓ define species
- ✓ classify organisms as the same or different species.

GET THINKING

There is great diversity among humans, as shown in Figure 6.5.1, yet we are all the same species. What makes us all human? What do you think being the same species means? Discuss this with other students in your group and come up with a definition of species. As you work through this module, reflect on your definition and refine it with your new knowledge.



▲ FIGURE 6.5.1 Humans are a diverse species.

Organisms

In Module 6.4, you learned that living things can move, respire, respond to stimuli, grow, reproduce, excrete wastes and gain nutrition. All living things are called **organisms**.

organism
a living thing



▲ FIGURE 6.5.2 The koala is gaining nutrition from the leaves of the eucalyptus tree. The koala and eucalyptus are both organisms.



Interactive resource
Drag and drop: What
is a species?

Species

species

a group of similar organisms that can breed to produce fertile offspring

fertile

able to produce offspring

Organisms are commonly classified into groups called **species**. All members of a species have similar characteristics and can breed with one another to produce **fertile** offspring, which means that the offspring can also produce offspring.

Sometimes it is easy to classify organisms into their species. For example, you would easily identify an organism as a dog or a cat or a horse. Other organisms may be more difficult to tell apart. For example, a Damara sheep looks very similar to a goat (Figure 6.5.3). In these instances, scientists use information other than an organism's appearance to classify them.



▲ FIGURE 6.5.3 (a) The Damara sheep and (b) a goat. Although they look similar, they cannot interbreed to produce fertile offspring, so they are classified as different species.

Hybrid

sterile

cannot produce offspring

hybrid

the offspring of a mating between two different species

Some species can interbreed, but the offspring are **sterile**. This means that they cannot reproduce. These offspring are called **hybrids**.

An example of this is the donkey and horse. If a male donkey breeds with a female horse, they produce a mule. Mules are sterile hybrids and not a species.



▲ FIGURE 6.5.4 A mule is a hybrid produced by a cross between two species, a donkey and a horse.

Classifying within species

You just need to look at a group of dogs to see that there is a lot of variation within a species. When organisms are adapted to live with humans, they are **domesticated**. By controlling the breeding of domestic organisms, humans have produced organisms with specific features. These are known as different **breeds**. For example, Great Danes and chihuahuas are both the same species but are different breeds.

domesticated

adapted over generations to live with humans

breed

a group of organisms of the same species with distinctive features



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▲ FIGURE 6.5.5 Great Danes and chihuahuas are both in the same species but are different breeds of dogs.

6.5 LEARNING CHECK

1 Define:

- a species.
- b hybrid.
- c breed.

2 Describe the difference between fertile and sterile.

3 Humans can look very different from one another. **Explain** why humans are all classified as the same species.

4 **Explain** why it is advantageous to classify organisms into species.

5 A liger is produced from a male lion and a female tiger. **Discuss** whether a liger is a species or a hybrid.



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SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THIS SKILL:

- ▶ creating a dichotomous key by observing and classifying Australian animals based on their physical characteristics.

CONSTRUCTING AN AUSTRALIAN ANIMAL DICHOTOMOUS KEY

AIM

To create a dichotomous key to classify Australian animals

MATERIALS AND EQUIPMENT

- pictures of each of the Australian animals shown in Figure 6.6.1
- large piece of paper or a whiteboard
- pens

PROCEDURE

Work individually or in groups of two or three. You can create a tree diagram or a linked key. See Module 6.2 for examples.

- 1 Observe each animal in Figure 6.6.1 carefully.
- 2 For each animal, list all the physical features that you can observe. For example, kangaroo: long tail, stands on two legs, long ears, light fur. Do not include any information you can't see, such as behaviour or diet.
- 3 Begin your dichotomous key by dividing the animals into two groups based on two opposite characteristics. For example, fur and no fur.
- 4 Divide each of the two groups into two smaller groups, based on similar characteristics.
- 5 Repeat step 4 until there is only one animal per group.

RESULTS

Take a photo of your dichotomous key or draw it in your workbook.

ANALYSIS

- 1 Which features were easiest to observe? Why?
- 2 Compare your dichotomous key to those of the other groups. What are the similarities and differences?
- 3 Do you think this type of classification is useful? Why?
- 4 Different species of kangaroo have very similar physical characteristics. If you had to classify the different species, what other characteristics would you add to your dichotomous key?



Goanna



Brown snake



Cassowary



Pelican



Platypus



Dingo



Koala

▲ FIGURE 6.6.1 Australian animals to use in your dichotomous key

6.7

Adaptations of Australian species

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define adaptation
- ✓ explain the three main types of adaptations: structural, behavioural and physiological
- ✓ describe adaptations of Australian species.



Video activity
How Australian animals adapt

GET THINKING

Australia is a very hot and dry continent. As a result, many Australian animals and plants have to survive extreme conditions, such as high temperatures and a lack of water. If you had to live in these hot, dry conditions, what would you need to do to survive? Is your body adapted to this type of environment? What are the differences and similarities between your body and that of a kangaroo? Create a Venn diagram to illustrate those differences and similarities.

Adaptations

adaptation

a change over generations that makes a species more suited to surviving and reproducing in a particular environment

structural adaptation

a change to a physical feature or structure of a species that makes it better suited to its environment

behavioural adaptation

a change to how a species behaves in response to its environment

physiological adaptation

a change to a species' organs, cells or cellular processes that makes it better suited to its environment

cell

the basic structural unit of all living things

evolved

changed slowly over many generations

An **adaptation** is the result of changes in a species that happen over many generations and that make the species better able to reproduce and survive in its environment. There are three main types of adaptations: structural adaptations, behavioural adaptations and physiological adaptations. **Structural adaptations** are physical changes you can see on the outside of the organism. **Behavioural adaptations** are changes in how an organism behaves in response to conditions in its environment. **Physiological adaptations** are internal changes in an organism's organs, **cells** or cellular processes.

Australia is a large, isolated continent with unique species of animals and plants that are well adapted to its often harsh environments. Many living things in Australia have **evolved** adaptations that help them cope with extreme conditions, such as droughts, high temperatures and bushfires.

Adaptations in Australian animals

Australia has a wide variety of animals that have adapted to their very different types of environments over time. Examples of different types of adaptations in Australian animals are shown in Table 6.7.1.

▼ TABLE 6.7.1 Examples of structural, behavioural and physiological adaptations in Australian animals

Type of adaptation	Example in Australian animals
Structural	<ul style="list-style-type: none"> • Kangaroos' large ears help cool them down. • Lizards' tough leathery skin keep them cool and reduce water loss. • Echidnas have backwards-facing hind legs to push dirt out of the way while burrowing (Figure 6.7.1a).
Behavioural	<ul style="list-style-type: none"> • Wombats run to their burrows to avoid predators (Figure 6.7.1b). • Kangaroos lick their paws to cool down. • Reptiles bask in sunlight to regulate their body temperature.
Physiological	<ul style="list-style-type: none"> • Kangaroos produce concentrated urine to conserve water. • Some snakes use venom to kill other animals (Figure 6.7.1c).



▲ **FIGURE 6.7.1** (a) The echidna's backwards-facing hind legs is an example of a structural adaptation; (b) wombats use burrows to stay safe from predators, which is a behavioural adaptation; (c) tiger snake venom is an example of a physiological adaptation.

Adaptations in Australian plants

Plants are found in every type of environment in Australia, from sandy deserts to alpine areas. Like animals, Australian plants have a range of adaptations that make them perfectly suited to their environments. Some examples are shown in Table 6.7.2.

▼ **TABLE 6.7.2** Examples of structural, behavioural and physiological adaptations in Australian plants

Type of adaptation	Example in Australian plants
Structural	<ul style="list-style-type: none"> Some gum trees have blue-grey leaves and light-coloured bark to reflect the heat (Figure 6.7.2a). Plants in the desert have reduced leaf size to reduce water loss. Many Australian plants have seeds covered by woody cones and waxy leaves to survive bush fires and dry conditions.
Behavioural	<ul style="list-style-type: none"> Some trees have leaves that can move to hang vertically to reduce exposure to the heat of sunlight (can also be classified as physiological). Some plants can shed some leaves during very hot days to reduce dehydration (can also be classified as physiological).
Physiological	<ul style="list-style-type: none"> Wattle trees have low oil content in bark to reduce burning in bush fires. The gympie gympie stinging tree has toxins that are like the toxins found in venomous spiders (Figure 6.7.2b).



▲ **FIGURE 6.7.2** (a) Ghost gums are found in hot, dry areas and have pale bark and pale, waxy leaves to reduce water loss; (b) gympie gympie stinging trees have potent toxins, an example of a physiological adaptation.

☆ ACTIVITY

Adaptations in your local environment

In this activity, you will visit local bushland to make observations and do some research on Australian plants.

Materials and equipment

- magnifying glass
- an area outside your classroom, for example bushland in your school grounds, a native garden, a local reserve or a park
- device to take photos
- notebook

Procedure

Work in groups of two or three.

- 1 Observe the environment around you. Is it dry or humid? How many trees and shrubs are growing there? Can you see any traces of animals, such as animal droppings, tracks or burrows or nests?
- 2 Once you have noted those observations, choose two Australian native plants you have observed. Ensure they are quite different from each other.
- 3 Take a photo of each plant.
- 4 Once in the classroom, do some research about your chosen plants.
 - a Find out their common names.
 - b What adaptations do they have? Explain how these adaptations relate to their environment.
 - c Where else in Australia are these plants found?
 - d As an extension activity, you could find out the scientific name of each plant, and see if they belong to the same species, genera or family. You will learn more about scientific names in the next module.
- 5 Write a scientific report about your findings.

! Safety

Be aware of your surroundings to avoid tripping over branches or uneven surfaces. Use insect repellent and sunscreen.

6.7 LEARNING CHECK

- 1 **Define** adaptation.
- 2 **a Explain** the three main types of adaptations: structural, behavioural and physiological.
b List examples of Australian animals and plants for each type of adaptation.
- 3 You are a reptile park ranger. You are in charge of creating enclosures for reptiles. A red-bellied black snake will arrive in a couple of months.
 - a **Research and describe** some of the snake's adaptations, including the type of adaptation (structural, behavioural or physiological).
 - b **Explain** how you are going to cater for the snake's adaptations in the design of your enclosure.



Ken Griffiths/Shutterstock.com

6.8 Linnaean classification of living things

6.8

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe the Linnaean classification of living things
- ✓ discuss the advantages of a common method of classifying living things
- ✓ justify the size of each group in the Linnaean classification system.

GET THINKING

Mnemonics can help you remember lists of words or facts. In this module, you will need to remember these words, in order:

Kingdom, **P**hylum, **C**lass, **O**rders, **F**amily, **G**enus and **S**pecies.

Use the first letter of every word to make a saying that you will remember. For example, **K**ings **P**refer **C**rowns **O**F **G**reat **S**ize. Use this during the module to remember the words.



Video activity
Carl Linnaeus' classification system

Interactive resource
Label: Levels of classification

Linnaean classification system

There is a huge number of different types of organism on Earth. One estimate is that there are 8 700 000 different species in total, 6 500 000 of them living on land and 2 200 000 living in fresh water or the ocean. Given there are so many, an efficient method of classifying them is important. The **Linnaean classification system** used by scientists provides information about the characteristics of organisms in a group and the relationships between groups of organisms. This system is used internationally, providing a common method of classification for scientists everywhere. This allows them to:

- communicate with clarity
- understand each other's work
- collaborate to build an understanding of living things.

The science of classifying organisms is called **taxonomy** because it involves organising organisms into groups called **taxa** (singular taxon). This system also enables scientists to name living things.

Carl Linnaeus

Carl Linnaeus is considered the father of taxonomy. He was born Carl von Linné on 23 May 1707, at Stenbrohult, in southern Sweden. His father, a Lutheran pastor, was a keen gardener and so young von Linné loved plants from when he was young. He disappointed his parents by showing no interest in the priesthood; instead, he entered the University of Lund in 1727 to study medicine. A year later, he transferred to the University of Uppsala, the most prestigious university in Sweden. He spent most of his time at Uppsala collecting and studying plants. Despite being poor, he organised expeditions to Lapland in 1731 and to central Sweden in 1734 to study plants.

Carl von Linné's work led him to develop a classification system of living things that was published in 1735 in the *Systema Naturae*. In 1741, he gained a professorship at Uppsala. Here he restored the university's garden, arranging the plants according to his system of classification. Carl von Linné Latinised his name and became known as Carolus Linnaeus.



▲ **FIGURE 6.8.1** A statue of Carl Linnaeus – the father of taxonomy

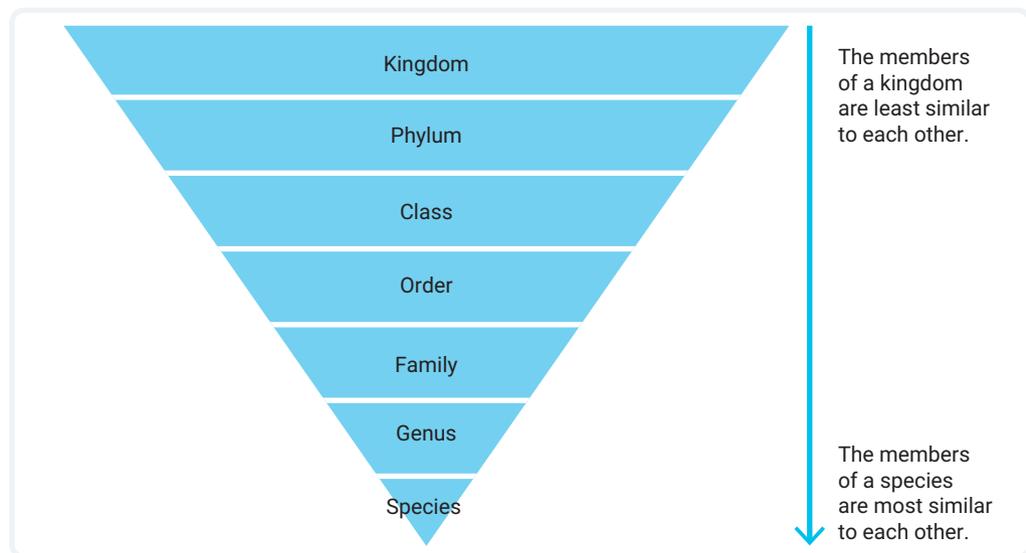
Divisions in the Linnaean system

structure
how something is built
or organised

The Linnaean classification system groups organisms based on their **structure** and characteristics. Because these features are inherited, the groupings indicate the degree to which organisms are related. All living things are initially classified into large groups based on a few similarities. Each group is then divided into smaller and smaller groups based on more and more similarities. This continues until there is only one species in each group.

The first level of grouping is kingdom. There are five kingdoms: Animalia, Plantae, Fungi, Protista and Monera (Bacteria). Some scientists also include a sixth kingdom of Archaeobacteria. You will learn more about the different kingdoms in Module 6.9.

Each kingdom is divided into smaller groups called phyla. Each phylum divides into classes, each class divides into orders, each order divides into families, each family divides into genera (singular: genus) and each genus divides into species. This division is summarised in Figure 6.8.2.



▲ FIGURE 6.8.2 The levels of Linnaean classification

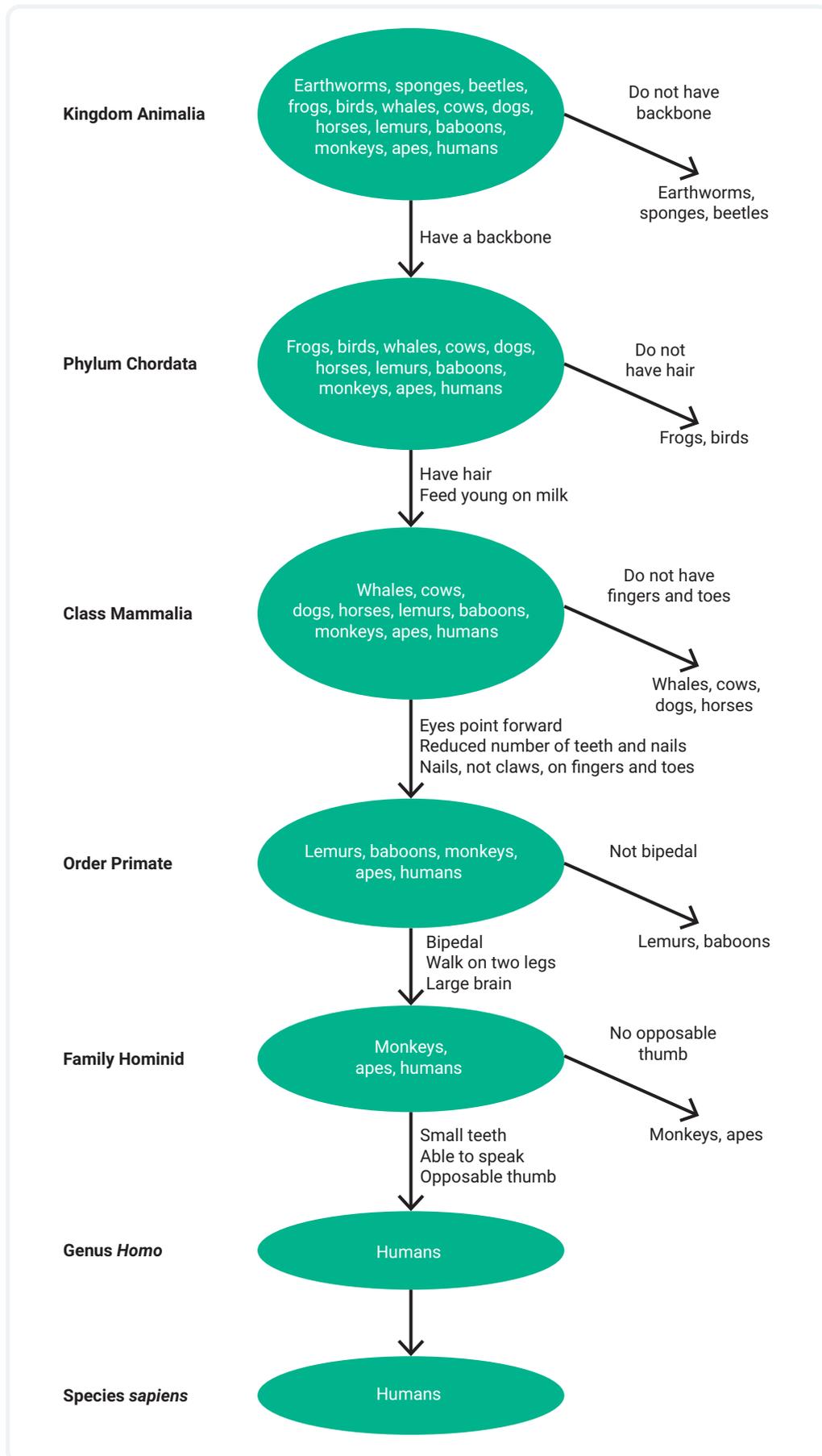
hierarchical
in order of importance

As you move down the **hierarchical** levels, there are fewer organisms in each group. However, the organisms become more and more similar because, at each division, the characteristics used to organise the groups become more specific. This increased similarity is due to organisms being more closely related. Therefore, scientists use taxonomy to indicate how closely species are related.

analogy
a comparison

A deck of cards can be used as an **analogy** to explain this. In the whole deck, there are 52 cards. If we split it into red cards and black cards, there are now only 26 cards in each group. Cards within each group have two characteristics in common – they are cards and they all have the same colour. If we split the red cards into hearts and diamonds, there are now only 13 cards in each group. However, they now have three things in common – they are a card, they are the same colour, and they have the same symbol.

Figure 6.8.3 outlines the classification of humans and Table 6.8.1 outlines the classification of the river red gum. Note how each species is classified into a particular group at each hierarchical level. Also note that plant classification uses the term ‘division’ instead of ‘phylum’.

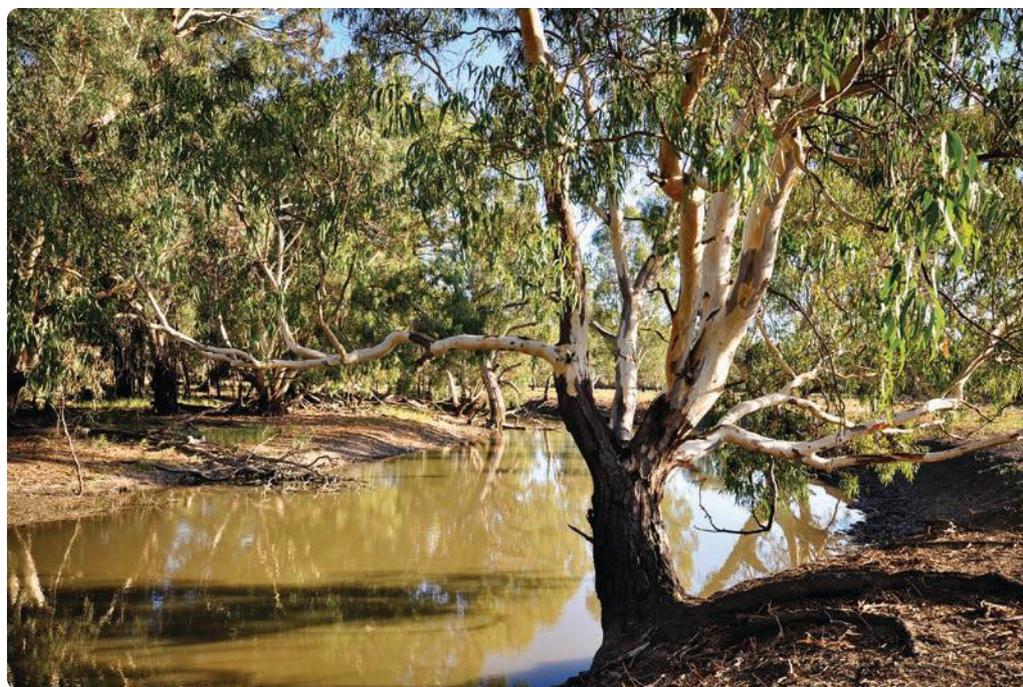


▲ FIGURE 6.8.3 The classification of humans

▼ TABLE 6.8.1 The classification of river red gums

Level of classification	Example	Features of the group	Organisms found in this group
Kingdom	Plantae	<ul style="list-style-type: none"> • Multicellular • Complex cell structure, produce their own food by photosynthesis 	Eucalypt, pine tree, pomegranate, guava, grass, fern, moss, green algae
Division*	Magnoliophyta	<ul style="list-style-type: none"> • Possess a transport system • Have seeds and flowers 	Eucalypt, pomegranate, guava
Class	Magnoliopsida	<ul style="list-style-type: none"> • Dicotyledons – have two seed leaves 	Eucalypt, pomegranate, guava
Order	Myrtales	<ul style="list-style-type: none"> • Woody plants, often with flaky bark 	Eucalypt, pomegranate, guava
Family	Myrtaceae	<ul style="list-style-type: none"> • Evergreen leaves • Leaves contain essential oils 	Eucalypt, guava
Genus	<i>Eucalyptus</i>	<ul style="list-style-type: none"> • Gumnuts covered by a woody cap 	Eucalypt
Species	<i>camaldulensis</i>	<ul style="list-style-type: none"> • Can grow up to 45 m tall • Pointed gum nut 	River red gum

*Plant classification uses division instead of phylum.



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▲ FIGURE 6.8.4 The river red gum is classified as *Eucalyptus camaldulensis*.

Modelling Linnaean classification

Models and analogies are useful to explain complex problems. In this task, you are going to use an analogy to model the Linnaean classification of living things.

Materials and equipment

Per class:

- pencil case with a wide range of objects
- pictures of items commonly found in a kitchen (e.g. large plate, small plate, mug, glass, bowl, knife, spoon, fork, teaspoon, measuring cup, measuring spoon, oven, microwave, stove, mixing bowl, saucepan, wooden spoon, cake tin)
- pictures of items in a supermarket (e.g. apple, orange, banana, orange juice, milk, soft drink, bread, soup, rice, pasta, washing powder, dishwashing liquid, cleaning spray, shampoo, conditioner, hand soap, tissues, notebook, cat food, dog food, chocolate, potato chips)
- device to record a video (if possible)

Procedure

Work in groups of two or three.

- 1 Choose one analogy for Linnaean classification.
 - Items in a pencil case
 - Items in a kitchen
 - Items in a supermarket
- 2 Discuss how these items can be classified into a hierarchy similar to the Linnaean classification.
- 3 Discuss how your analogy demonstrates how the items in a group become more similar as you move down the hierarchy, but there are fewer items in each group.
- 4 Model this classification, using your items or photos.
- 5 Plan and create a method of sharing your analogy and model with other members of the class. For example, create a video or a poster, or do a short oral presentation.

Analysis

In what ways did your analogy and model accurately reflect the Linnaean classification of living things and in what ways was it inaccurate?

6.8 LEARNING CHECK

- 1 **List** the classification levels, in order.
- 2 Which level of classification contains groups with the most:
 - a similarities?
 - b organisms?
- 3 Roses and plum trees both belong to the Rosaceae family but they belong to different genera. Would they be more similar or less similar than two plants in the same genera? **Explain** your answer.
- 4 Conduct research into the taxonomy of the bottlenose dolphin. **State** the name of the group it is classified in for each level of classification.

6.9 The kingdoms of living things

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ list the five kingdoms of living things
- ✓ describe the key characteristics of each kingdom.

GET THINKING

In Linnaeus's original classification, there were only two kingdoms: plants and animals.

- 1 Why do you think Linnaeus only included these two kingdoms originally?
- 2 Why do you think there are now more kingdoms?

Classifying organisms into kingdoms

Organisms are classified into kingdoms based on key characteristics that are constant over the organism's life. These include:

- the number of cells in the organism (**unicellular** or **multicellular**)
- whether the cells are simple or complex
- how the organism obtains its food.

unicellular

composed of only one cell

multicellular

composed of many cells

heterotroph

an organism that cannot make its own food and so gains nutrition by ingesting other sources



Quiz
Kingdoms

Interactive resource
Match: Kingdoms

autotroph

an organism that can make its own food

photosynthesis

the process by which plants use light energy from the Sun to produce simple sugars (e.g. glucose) in a series of chemical reactions

Kingdom Animalia

You can easily identify some things as animals, including birds, fish, humans, snakes, worms, spiders and jellyfish. But what characteristics are common for all animals?

For an organism to be classified as an animal, it must be made of more than one cell (multicellular) and the cells must be complex. This means that they contain structures that carry out certain functions.

Animals are known as **heterotrophs** because they cannot make their own food. Instead, they must ingest (eat) their food to gain the energy and chemicals needed.



Shams F Amir/Shutterstock.com

▲ FIGURE 6.9.1 A rhinoceros is classified in kingdom Animalia.

Kingdom Plantae

This kingdom consists of plants, including grasses, trees, shrubs, ferns and mosses. They have many structural similarities to animals because they are made up of many complex cells. However, plants are **autotrophs** because they can produce their own food through a process called **photosynthesis**. This is possible because plant cells have specialised structures that can use the Sun's energy to produce sugar.



MEE KO DONG/Shutterstock.com

▲ FIGURE 6.9.2 Plants use the Sun's energy to make their food.

Kingdom Fungi

The kingdom Fungi includes organisms such as mushrooms, toadstools, yeasts and moulds. These species are made of complex cells enclosed by a strong cell wall containing a substance called chitin. Most fungi are multicellular; however, yeasts are unicellular (Figure 6.9.3).



iStock.com/Jannicke Wiik-Nielsen

▲ FIGURE 6.9.3 A magnified photo of yeast taken with a scanning electron microscope. Each yeast is made of only one cell.



AlmostViralDesign/Shutterstock.com

▲ FIGURE 6.9.4 Mushrooms are multicellular fungi.

Although fungi have many similar characteristics to plants, their way of obtaining food is different. Fungi cannot make their own food. Instead, they get their nutrition from decaying matter; this makes them heterotrophs. Fungi are different from other heterotrophs, including animals, because they use chemicals to break their food down before absorbing it.

Kingdom Protista

The kingdom Protista contains all organisms made of complex cells that are not fungi, plants or animals. Because of this broad definition, there is a lot of variation within this kingdom. However, most protists are unicellular and microscopic.

Some protists, such as green algae, are autotrophs. Others, such as paramecium, are heterotrophs (Figure 6.9.5).

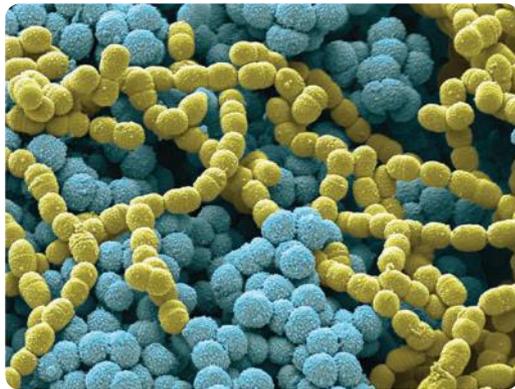


iStock.com/micro_photo

▲ FIGURE 6.9.5 *Paramecium caudatum* is a species in the kingdom Protista.

Kingdom Monera (also known as kingdom Bacteria)

There are more than 30 000 named species of bacteria, including *Escherichia coli* (*E. coli*), *Streptococcus pyogenes* (Strep) and *Staphylococci epidermidis* (Staph). Bacteria are found everywhere: in soil, water, plants and animals, and within the earth. Some bacteria are harmful, but most are beneficial because they support organisms. For example, there are up to 1 000 000 000 000 000 (10^{15}) bacteria in the digestive system of a horse. The bacteria break down food so that the horse can absorb the nutrients.



▲ FIGURE 6.9.6 Bacteria seen through a scanning electron microscope



▲ FIGURE 6.9.7 Bacteria can be grown on agar plates. Each dot on the plate contains millions of bacteria cells.

All bacteria are unicellular organisms with a simple cell structure. They are so small that between 20 000 and 1 million bacteria lined up in a row would be just 1 metre in length!

With such a large number of species of bacteria, it is easy to understand that there is great diversity between them. This includes their source of nutrition, as some are heterotrophs while others are autotrophs.

Other kingdoms

As scientists gain new knowledge and understanding, they adapt their theories and models. For example, the development of the scanning electron microscope allowed us to see things in much greater detail than ever before. Based on this new information, some scientists have proposed dividing living things into more kingdoms.

One suggestion is that there should be a sixth kingdom, kingdom Archaeobacteria (or kingdom Archaea) containing simple, unicellular organisms that are different from bacteria. These organisms can survive in extreme environments such as those with very high salinity, very high temperatures and high acidity. When this sixth kingdom is included, the original kingdom Monera (or Bacteria) is divided into kingdom Eubacteria and kingdom Archaeobacteria. Archaeobacteria are considered to be primitive bacteria and Eubacteria are considered to have evolved more recently.

Summarising the characteristics of the five kingdoms

Table 6.9.1 summarises the characteristics of the organisms in the five kingdoms.

▼ TABLE 6.9.1 A summary of the characteristics of organisms in the five kingdoms

Kingdom	Number of cells	Complexity of cells	Method of nutrition
Animalia	Multicellular	Complex	Heterotroph
Plantae	Multicellular	Complex	Autotroph (photosynthesis)
Fungi	Unicellular or multicellular	Complex, contain chitin in the cell wall	Heterotroph (decaying matter)
Protista	Unicellular	Complex	Autotroph or heterotroph
Monera (Eubacteria)	Unicellular	Simple	Autotroph or heterotroph
Monera (Archaeobacteria)	Unicellular	Simple, survive in extreme conditions	Autotroph or heterotroph

6.9 LEARNING CHECK

- 1 Name** the kingdoms that include organisms with a complex cell structure.
- 2 List** the characteristics of organisms in the plant kingdom.
- 3 Name** the kingdom with organisms that are made up of many complex cells and who cannot make their own food.
- 4 Explain** why an organism would be classified as an animal and not a plant.
- Euglena* are single-celled organisms found in many aquatic environments. Their cells are quite complex, including the presence of a whip-like extension called a flagellum. *Euglena* also contain structures that allow them to undergo photosynthesis. However, they can also absorb food from the environment. What kingdom would *Euglena* be classified in? **Justify** your answer.
- Originally, fungi were classified in the plant kingdom.
 - a Suggest** why they were originally thought to be plants.
 - b Explain** why they can no longer be classified as plants.
- Conduct research to **identify** the kingdom for each of the following organisms.
 - a** Diatom
 - b** Dugite
 - c** Anthrax
 - d** Gardenia
 - e** *Penicillium*
- Each kingdom is divided into phyla or divisions. Use the internet to **investigate** the phyla in the animal kingdom. What is the name of each phylum and what type of animal does it contain?

6.10 Naming living things

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define binomial nomenclature
- ✓ describe how organisms are named.

GET THINKING

Table 6.10.1 shows the common and scientific names for some well-known organisms. What do you notice about all the scientific names and how they are written? List three things that they have in common. As you work through this module, reflect on your answer – did you predict the rules for writing scientific names?

▼ TABLE 6.10.1 The common and scientific names of some well-known organisms

Common name	Scientific name
Human	<i>Homo sapiens</i>
Domestic cat	<i>Felis catus</i>
Venus flytrap	<i>Dionaea muscipula</i>
Button mushroom	<i>Agaricus bisporus</i>

Scientific names

The word for ‘cat’ is different in different languages: *katze* in German, *chat* in French, *gatto* in Italian, *neko* in Japanese and *kucing* in Indonesian. It makes it difficult to talk about cats if you are not speaking the same language. However, if you ask an English, German, French, Italian, Japanese or Indonesian scientist the scientific name for a cat, the answer will be the same: *Felis catus*.



Video activity
Naming species

Extra science
investigation
Identifying insects



istock.com/georgeolsson

▲ FIGURE 6.10.1 The scientific name for a domestic cat is *Felis catus*.

Binomial nomenclature

In Table 6.10.1, you would have noticed that the genus name for humans is *Homo*, and the name at the species level (the **specific name**) is *sapiens*. The scientific name for humans is made up of the genus name together with the specific name – *Homo sapiens*. This is also shown in Table 6.8.1, where the genus name for the river red gum is *Eucalyptus* and the specific name is *camaldulensis*; hence, the scientific name for the river red gum is *Eucalyptus camaldulensis*. This two-word naming system is known as **binomial nomenclature**.

specific name

the second part of the scientific name, which identifies the species within a genus

binomial nomenclature

a two-word naming system for naming living things

Naming conventions

When writing scientific names, there are conventions, or rules, to follow.

- 1 The scientific name is in italics. This is because it is in Latin and also distinguishes it from other text. If you are handwriting the names, underline them instead.
- 2 The genus name is always written first and begins with a capital letter. The species name is always written second and begins with a lower-case letter.
- 3 If the same scientific name occurs more than once in the same piece of writing after it is used in full the first time, the genus name may be abbreviated to its first letter, such as *H. sapiens* or *E. camaldulensis*.

Comparing scientific names

Within a genus, the species are often distinguished with descriptive names. For example, there are approximately 900 different species in the *Eucalyptus* genus. The scientific name for each species begins with *Eucalyptus*, but each one has a different specific name to identify it. *Eucalyptus longifolia* is named for its long (*longus*) leaves (*folium*), and *Eucalyptus grandis* is named for its large size (*grandis*) (Figure 6.10.2).



▲ FIGURE 6.10.2 (a) *Eucalyptus longifolia* is named for its long leaves, whereas (b) *Eucalyptus grandis* is named for its large size.

This method means that the same specific name can be used for species in more than one genus. However, each species will have its own, unique scientific name because it is the combination of the genus and specific name that identifies each species. For example, the New Zealand iris is named *Libertia grandiflora* because *grandiflora* means large flowers. The Bull Bay magnolia also has large flowers, and its scientific name is *Magnolia grandiflora*. Even though both plants have the same specific name, they are in different genera. The lily magnolia (*Magnolia liliiflora*) is in the same genus as the Bull Bay magnolia. This means that the Bull Bay magnolia will have more in common with the lily magnolia than it does with the New Zealand iris, which is in a different genus.

Naming new species

When a new species is discovered, its kingdom, phylum and so on are determined on the basis of characteristics of groups that are already determined. In some cases, it will belong in a genus that already exists, and the new species simply needs a new specific name. For example, in 2021, scientists in Australia identified a new species of tree frog belonging to the genus *Litoria*. The species, *Litoria quirritatus*, is named for its high-pitched call, as *quirito* means a shriek or scream in Latin.



Weblink
The screaming tree frog



Ken Griffiths/Shutterstock.com

▲ **FIGURE 6.10.3** The screaming tree frog (*Litoria quirritatus*) was identified and named in 2021.

Other organisms will not fit into predetermined groups, and so scientists make a new group. This was the case with a new species of brittle star discovered in 2015 by Australian scientist Tim O'Hara. O'Hara found the organism in specimens that had been collected in the south-west Pacific Ocean near New Caledonia. The new brittle star has eight snake-like arms with rows of hooks and spines, and a row of teeth along every jaw. It is so different from other brittle stars that a new family and genus was created for it. It was named *Ophiojura exbodi* because it was collected during the EXBODI expedition.



Jay Black (University of Melbourne) and Tim O'Hara (Museums Victoria)

▲ **FIGURE 6.10.4** *Ophiojura exbodi* is a species of brittle star that was only discovered and named in 2015, in the newly created family Ophiojuridae.

Research activity

☆ ACTIVITY

6.10

Scientific names of organisms found in Australia

Figure 6.10.5 shows the common names and photos of some organisms found in Australia. Your task is to research the scientific name for each organism, where they are found and their key features. Use this information to write a paragraph with a possible explanation for why each one was given that particular name.



Agile wallaby



Umber amanita mushroom



Eastern rainbow fish



Pied imperial pigeon



Yellow shower



Kauri pine

▲ FIGURE 6.10.5 Some Australian organisms

6.10 LEARNING CHECK

- 1 How many words are in the scientific name of an organism?
- 2 Why are scientific names written in italics?
- 3 **Explain** why the scientific name for an organism is the same around the world.
- 4 Tapeworms have a ribbon-like body composed of a series of segments. The different species of tapeworm vary in the organism they infect.
 - a **Apply** the information in the table below to write the scientific name for this tapeworm.

Level of classification	Name
Kingdom	Animalia
Phylum	Platyhelminthes
Class	Cestoda
Order	Cyclophyllidea
Family	Taeniidae
Genus	<i>Taenia</i>
Species	<i>ovis</i>

- b **Name** the organism that this tapeworm infects. You may need to do some research to find this answer. Which part of the tapeworm's name indicates the organism that it infects?

6.11 Classification systems

**IN THIS MODULE
YOU WILL:**

✓ examine Aboriginal and Torres Strait Islander Peoples' classification systems.

Classification systems

For thousands of years, Aboriginal and Torres Strait Islander Peoples have observed and learned from the complex interrelationships between organisms in their natural environments. They have used these observations to develop culturally specific and complex classification systems for organisms.

The different classification systems developed by many Aboriginal and Torres Strait Islander Peoples across Australia reflects the diverse environments each Nation encompasses. However, there are many similarities in the systems that Aboriginal and Torres Strait Islander Peoples use to classify living things. For example, many classification systems include criteria relating to an organism's physical characteristics, behaviour and habitat. Sub-classifications may incorporate life cycle stage, sex, age or reference to a particular custom or practice.

Many Aboriginal and Torres Strait Islander Peoples classify living organisms into plant or animal groups. Animal life may then be divided into groups based on observable characteristics and habitats, such as land animals, marine animals and winged organisms.

Similar to the Linnaean system of classification, many Aboriginal and Torres Strait Islander Peoples' classification systems are hierarchical, with organisms grouped in levels.

Classifying animals

The Yolngu Peoples of north-eastern Arnhem Land in the Northern Territory have a highly structured system for classifying plants and animals, in which animals showing similar features are grouped together. For example, birds are placed in a group called *warrakan*. Within this group is a subgroup for small birds, called *djikay*. Within this subgroup is another smaller group for finches, called *lidjilidji* (Figure 6.11.1). In this system of classification, each large group is made up of all the subgroups below it.

Source: Wikimedia Commons/Martybugs (talk) CC BY-3.0 SA



▲ **FIGURE 6.11.1** The Gouldian (rainbow) finch is part of the *lidjilidji* group within the Yolngu classification system. It was found in many northern areas across Australia but is now identified as endangered

The Yanyuwa Peoples of the Northern Territory classify living organisms as being either coastal and marine or inland. Organisms may be further sub-classified based on the particular habitat they occupy, such as open sea or intertidal zone. The Yanyuwa Peoples' language has a term, *walya*, that refers to all dugong and sea turtles. This category further subdivides to include 16 different names to distinguish between dugongs based on age, size, gender and status within its herd. These classifications indicate the importance of this animal to the Yanyuwa Peoples.



C. Jones. ©Commonwealth of Australia (Great Barrier Reef Marine Park Authority) 2019

▲ FIGURE 6.11.2 A dugong mother and calf

Classifying plants

The importance of plants as a resource for Aboriginal and Torres Strait Islander Peoples is reflected in their classification systems. Many classification systems distinguish plants as either wood-bearing or non-woody, highlighting the significance of wood in Aboriginal and Torres Strait Islander Peoples' material culture. For example, the Anindilyakwa Peoples of Groote Eylandt distinguish between woody plants (*eka*) and other plants (*amarda*) in the region. The woody plants are then sub-classified into a further eight categories based on the observation of a plant's form or habitat.

The classification of wood-bearing plants may also be based on function and use. In this classification, the wood-bearing plant may have a name based on the function of a finished object such as spear trees, shield trees, canoe trees or resin trees, and many other use-based categories. For example, the Pitta Pitta Peoples of the Boulia region in Queensland classify both the tree *Erythrina vespertilio* and the shields constructed from it as *koon-pa-ra*.



Joe Samboto

▲ FIGURE 6.11.3 This tree on Kaurua Country bears a scar from where a shield has been harvested from it.

Sharing knowledge

Aboriginal and Torres Strait Islander Peoples' detailed plant and animal knowledge and classification systems are instrumental in providing knowledge to scientists as they apply the Linnaean classification systems to the plants and animals of Australia. There are many instances where scientists thought they had discovered a 'new' species, only to be told the already existing names, cultural stories and detailed understanding of the 'new' species by Aboriginal and Torres Strait Islander Peoples.

- 1 Describe** the similarities between Aboriginal and Torres Strait Islander Peoples' and Linnaean classification systems.
- 2 Construct** a dichotomous key to represent the Yolngu People's classification system of birds.
- 3 Explain** the advantages of classifying living things based on function and use. Provide an example of where you could classify local plants on this basis.

☆ ACTIVITY

6.12 Changing classifications

BY THE END OF
THIS MODULE, YOU
WILL BE ABLE TO:

✓ explain how and why the classification of living things changes over time.



Video activity
What is taxonomy?

DATA SCIENCE

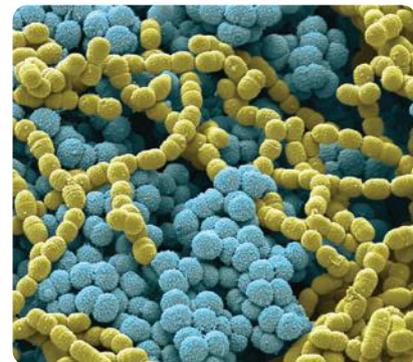


Learn more about
analysing scientific
models in
Module 2.10.

Changes at the kingdom level

Science is all about making observations, asking questions, developing an understanding of our world and using this understanding to solve problems. In any area of science, as people gain new information, scientists reflect on existing theories and models. The new information is added in to support or adapt what we previously believed.

This cycle occurs in taxonomy, leading to changes in classification. In Linnaeus's time, the first grouping was whether a living thing was a plant or an animal. If it was a plant, it was classified in the kingdom Plantae; if it was an animal, it was classified in the kingdom Animalia. With the search for more knowledge and the invention of microscopes, which enabled scientists to see cells, it was not so easy to classify living things into one of these two groupings. In 1866, a third kingdom, Protista, was proposed. This kingdom contained organisms made up of only one cell. As you learned in this chapter, it is now commonly accepted that there are five kingdoms. However, some scientists believe that there is evidence for up to eight kingdoms!



▲ FIGURE 6.12.1 Today, most scientists accept that there are five kingdoms: Animalia, Plantae, Fungi, Protista and Monera (Bacteria).

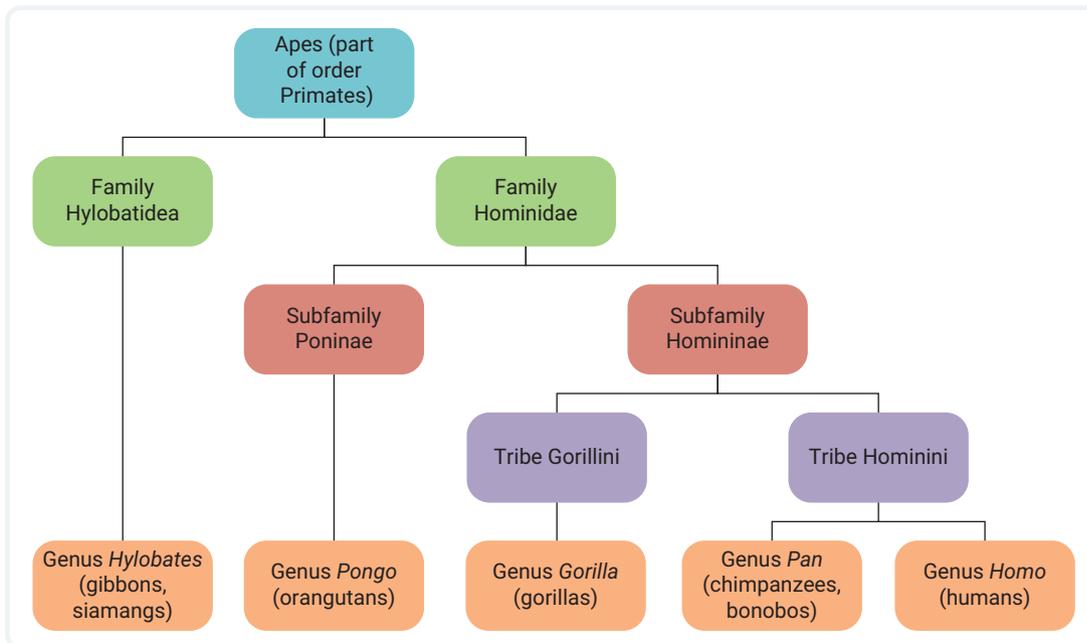
Changes to ape classification

Changes in classification also occur at levels lower in the hierarchy. We now have technology that allows us to look at an organism's genetic code. This depth of information provides greater detail than was previously available about the relationship between organisms.

One example of this change is in the apes, including humans. Originally, apes were grouped into three families:

- humans
- chimpanzees, gorillas and orangutans
- tree-dwelling apes such as the gibbon.

We now know that humans and chimpanzees are more closely related than this classification represented and so the classification was adjusted. Figure 6.12.2 represents the new classification of apes. Note that it includes the subfamily and tribe groups. These are further divisions of the Linnaean classification levels.



▲ FIGURE 6.12.2 The updated classification of apes



▲ FIGURE 6.12.3 Humans and chimpanzees are closely related, which is reflected in the updated classification of these species.

6.12 LEARNING CHECK

- 1 **Describe** how the number of kingdoms of living things has changed since Linnaeus first proposed his classification system.
- 2 **Describe** why classifications may change.
- 3 **Explain** why the number of ape families was changed.
- 4 Do you think there will be more, or fewer, changes in classification now than there were 50 years ago? **Discuss** the reason for your answer.

6 REVIEW

REMEMBERING

- 1 What are we doing when we classify something?
- 2 What does the 'di' in dichotomous mean?
- 3 What are the classifications in the Linnaean system based on?
- 4 **List** the seven levels of classification in order of increasing similarity.
- 5 **Define** species.
- 6 **List** three features shared by all members of the kingdom Animalia.
- 7 **Name** the smaller groups that a kingdom is divided into.
- 8 **State** the seven characteristics of all living things.

UNDERSTANDING

- 9 **State** two reasons why we classify objects.
- 10 What are the best types of features on which to base a classification system? **Justify** your answer.
- 11 How does the Linnaean classification system benefit scientists around the world?
- 12 Are organisms in the same genus more or less related than organisms in the same:
 - a class?
 - b species?
- 13 **Explain** where the scientific name for a species comes from.
- 14 Why are structural features used to classify organisms, rather than their colour?
- 15 **Explain** the difference between structural, behavioural and physiological adaptations and give an example of each.

APPLYING

- 16 **Apply** your knowledge of classification to create a classification system for these objects: wooden ruler, eraser, biro, black lead pencil, pencil sharpener, felt pen, protractor.

- 17 **Describe** a situation in which classification affects your life.
- 18 The first edition of *Systema Naturae* had only 13 pages. The 13th edition was published in 1770 and had 3000 pages. Why do you think the book increased in size so much?
- 19 Could the members of the kangaroo species *Macropus greyii* and *Macropus rufus* interbreed and produce fertile offspring? **Explain** your answer.
- 20 Search the internet to find the scientific names for the following organisms. **State** the scientific name and the abbreviated form of that name and **explain** how the name was chosen for that species.
 - a Sturt desert pea
 - b Firewood banksia
 - c California sea hare
 - d Spectacled bear
- 21 **Explain** why it would be important for a farmer to breed using only one species of wheat.
- 22 Why are *Euglena* and slime moulds placed into the kingdom Protista?
- 23 **Explain** how the species name *Ornithorhynchus anatinus* complies with the rules of binomial nomenclature.
- 24 Are members of the species *Aspergillus niger* more closely related to *Helleborus niger* or to *Aspergillus clavatus*?
Explain the reasons for your answer.
- 25 **State** an example of one Aboriginal or Torres Strait Islander classification system. **Describe** the basis on which the organisms are classified.

EVALUATING

- 26** Find two places in your home where a classification system is used. **Explain** what the system is, and how it assists in organising the items. Can you think of a better system to use?
- 27** **Explain** how our own names (first name and surname) could fit the rules of binomial nomenclature. How is our naming system similar to binomial nomenclature? How is it different?
- 28** The following table shows the common and scientific names of some cats.

▼ The big cats

Common name	Scientific name
Bobcat	<i>Lynx rufus</i>
Lynx	<i>Lynx canadensis</i>
Mountain lion	<i>Puma concolor</i>
African lion	<i>Panthera leo</i>
European wildcat	<i>Felis sylvestris</i>
Tiger	<i>Panthera tigris</i>
Jaguar	<i>Panthera onca</i>

- a** How many genera are represented in the table?
- b** How many different species are represented in the table?
- c** The scientific name of the domestic cat is *Felis catus*. Which cats in the table are most closely related to the domestic cat?

- 29** The gympie gympie stinging tree is one of Australia's most poisonous plants. Its leaves are covered in tiny hairs that are covered with toxins. Why do you think it is so poisonous? **Relate** your answer to what you have learned about adaptations of Australian animals and plants.
- 30** **Suggest** why the Linnaean system of classification doesn't include breeds.
- 31** Could an organism's diet be used as a basis for a classification system? **Explain** why or why not.
- 32** Classification systems also indicate how closely related objects within the system are. **Explain** if, and how, the Linnaean system achieves this.

CREATING

- 33** **Create** an imaginary organism from any kingdom. **Draw** a labelled diagram to represent your organism. Swap imaginary organisms with a partner. **Classify** each other's organisms according to the Linnaean classification system.
- 34** **Create** a tree diagram and a tabular form of a dichotomous key for different breeds of dogs.

SCIENCE IN DEPTH STUDY

#6

1 Connect what you've learned

Observe the photos of a range of organisms. Think about what you've learned in this chapter that relates to these organisms.

- What kingdoms are they classified in?
- How would they be named?
- What properties would be used to classify them?
- How could a dichotomous key be used to classify them?



2 Check your thinking

At the start of the chapter, you answered the following questions about the organisms in the photos.

- a What do they all have in common?
- b What are the main characteristics of each?
- c How can they be organised into groups?
- d How are they named?

Use the understanding that you have gained in this chapter to improve your answers. This process is similar to how scientists refine their understandings as they gain new knowledge.



3 Get into action

Use the characteristics of the organisms to develop a dichotomous key that could be used by another student to identify the name of each organism.



4 Communicate

Present your dichotomous key as one of the following.

- Tree diagram on a poster
- Linked (tabular) key in an A4 pamphlet
- A PowerPoint or Keynote presentation that uses links to move to the next choice



7

Cells

7.1 Cell theory (p. 256)

Cells are the basis of life.

7.2 Cells (p. 258)

The basic structure of a cell varies depending on the type of organism and the cell's function.

7.4 WORKING SCIENTIFICALLY: Drawing microscope observations (p. 267)

Using a light microscope to see and draw cells

7.3 Observing cells (p. 262)

Cells can be observed under the microscope.

7.5 Cell structures and processes (p. 268)

Photosynthesis occurs in the chloroplast and cellular respiration occurs in the mitochondrion.

7.7 Plant cells (p. 274)

Only plant cells have chloroplasts, large vacuoles and cell walls made of cellulose.

7.6 Animal cells (p. 272)

Animal cells have two exclusive organelles: centriole and lysosomes.

7.8 WORKING SCIENTIFICALLY: Preparing a wet mount and using a stain (p. 276)

Preparing a wet mount and using a stain to observe plant cells

7.9 Specialised cells (p. 278)

Specialised cells have a range of different structures that relate closely to their different functions.

7.10 Specialised cells in tissues and organs (p. 282)

Multicellular organisms are organised in a hierarchy order from cells, to tissues, to organs, to systems.

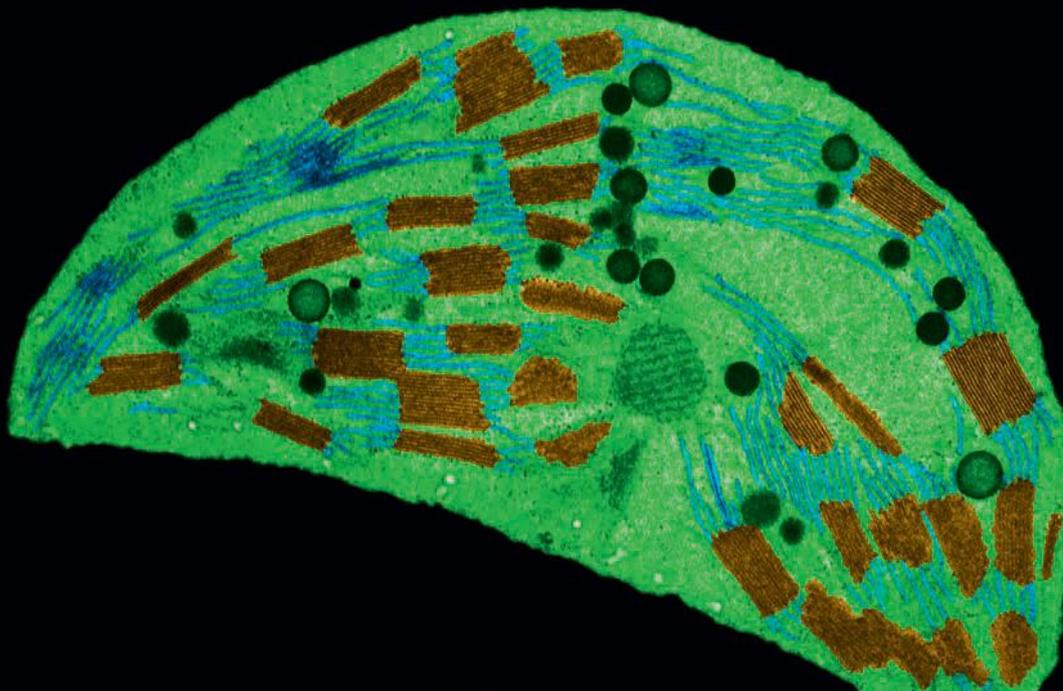
7.11 WORKING SCIENTIFICALLY: Science posters (p. 284)

Observing specialised cells under the microscope

7.12 SCIENCE IN CONTEXT: Technological developments and improved understanding of cells (p. 286)

The development of different types of microscopes has led to an improved understanding of cells.

Science History Images/Alamy Stock Photo



▲ **FIGURE 7.0.1** An electron micrograph of a chloroplast, where photosynthesis (the production of sugars using light energy) takes place.

Chloroplasts are specialised organelles (structures) in plant cells where photosynthesis takes place. Scientists believe that this organelle was once a bacterium that merged into another cell. Over millions of years, these cells evolved into part of the plant cell structure.

- ▶ How is the structure of the chloroplast related to its function?
- ▶ What is the process of photosynthesis?
- ▶ How does photosynthesis happen inside the chloroplast?
- ▶ How are sugars produced for the plant?

#7 DIVE INTO SCIENCE!

At the end of this chapter, you can complete Science in Depth Study #7. You can use the information you learn in this chapter to complete the project.

Assessments

- Prior knowledge quiz
- Chapter review questions
- End-of-chapter test
- Depth study: Secondary sources investigation/poster

Videos

- Science skills in a minute: Using a microscope (7.4); Science posters (7.11)
- Video activities: What is a cell? (7.1); The cell membrane (7.2); Photosynthesis (7.5)

Science skills resources

- Science skills in practice: Using a microscope to examine cells (7.4); Writing science posters (7.11)
- Extra science investigations: Effects of surface area (7.2); Examining plant cells (7.2); Modelling diffusion (7.2); Photosynthesis (7.5)

Interactive resources

- Label: Microscope (7.3); Animal cell (7.6); Plant cell (7.7)
- Drag and drop: Different types of cells (7.2); Cellular respiration (7.5); Plant cells (7.7)
- Crossword: Animal cells (7.6)



7.1 Cell theory

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ state the cell theory
- ✓ describe the role of technology in the development of the cell theory.



Video activity
What is a cell?

GET THINKING

What can you see in a puddle, a river or the ocean? Imagine the surprise felt by early scientists when they looked at water under their microscopes for the first time and saw tiny, living, single-celled organisms swimming around.

What is a cell?

A **cell** is the basic building block of all living things. All organisms are made up of cells. Living things can be made up of either a single cell or many cells. There are about 100 trillion (100 000 000 000 000), or 10^{14} , cells in the human body.

cytoplasm

a jelly-like substance that fills the inside of a cell

membrane

the thin layer that forms the outer boundary of a living cell, or of an internal cell compartment

organelle

a specialised structure in the cytoplasm of a cell that has a specific function

All cells are composed of a jelly-like substance called **cytoplasm**, surrounded by a thin **membrane**. The membrane separates the cytoplasm from its surroundings. Specialised structures called **organelles** are found in the cytoplasm.

The unfertilised ostrich egg is the biggest single cell in the world. The smallest known single cell, the bacteria *Pelagibacter ubique*, is mostly found in the oceans. The combined mass of all *Pelagibacter ubique* bacteria is more than that of all the fish in the sea. This makes it the most abundant organism on the planet.



▲ **FIGURE 7.1.1** The microscope was invented by Hans and Zacharias Janssen. This one was made in about 1880.

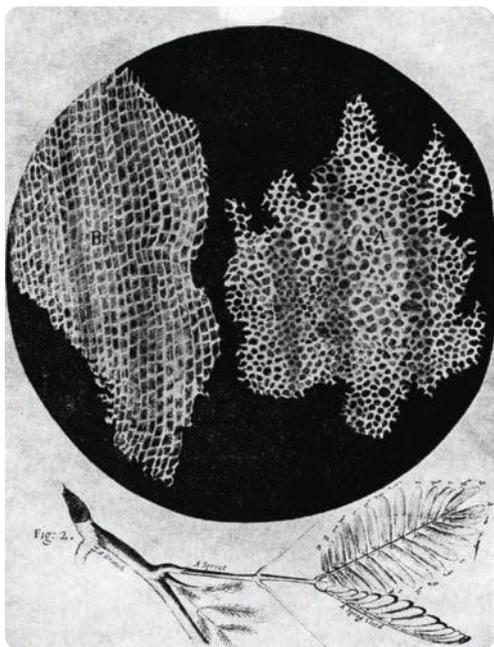
Microscopes led to the discovery of cells

Because cells are so small, the history of the discovery and understanding of cells is linked to the development of microscopes. Spectacle makers Hans and Zacharias Janssen, a Dutch father and son, invented the first microscope in 1590. They put several magnifying lenses inside a tube and discovered that the lenses made objects look much larger than they were (Figure 7.1.1).

English scientist Robert Hooke made significant improvements to the basic design of this first version of the microscope. He used microscopes to examine household items such as cloth and the point of

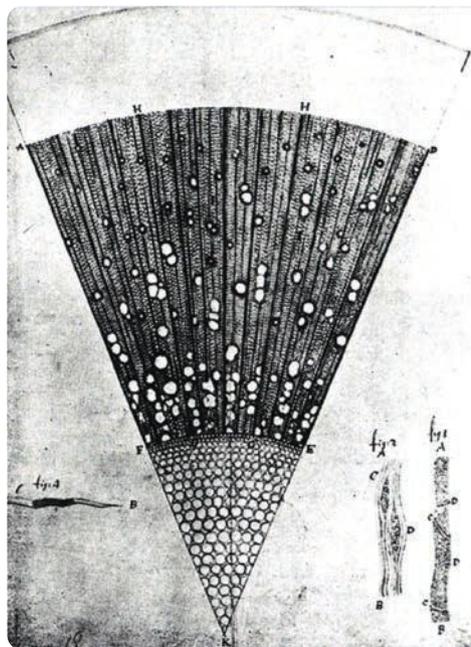
a needle. Hooke was the first person to use the term 'cell' in his book *Micrographia*, published in 1665. When examining dried cork, he thought that the box-shaped structures he saw through the microscope looked like small rooms, which were often referred to as 'cells' at the time (Figure 7.1.2).

Less than 10 years later, Antonie van Leeuwenhoek used the microscopes he developed to study organisms in pond water. His microscopes were able to magnify objects very clearly and enabled him to accurately draw yeast, bark, bacteria, blood cells and sperm (Figure 7.1.3).



Bettmann/Getty Images

▲ FIGURE 7.1.2 Cork cells under a simple microscope as Robert Hooke saw them in 1665



FLHC X17/Alamy Stock Photo

▲ FIGURE 7.1.3 A drawing of a section of ash tree made by Antonie van Leeuwenhoek

Cell theory

Further technological developments of the microscope continued over the next 150 years. These developments helped scientists to study the internal structure of cells, their functions and how they reproduce.

In 1839, scientists Matthias Schleiden and Theodor Schwann proposed two key ideas that would become important in our knowledge of cells: that organisms are composed of cells and that the cell is the smallest unit of all organisms. Twenty years later, Rudolf Virchow showed that new cells can only arise by cell division of existing cells. These three ideas have been combined into the **cell theory**, which states the following.

- All living things are made up of cells.
- Cells are the basic building blocks of all organisms.
- Cells come from pre-existing cells; that is, new **daughter cells** are formed from the division of **parent cells**.

cell theory

the basic theory in modern cell biology that states that all living things are made up of cells, cells are the basic units of all living things, and cells form from existing cells

daughter cells

two cells that result from the division of a parent cell

parent cell

the original cell that divides to form two daughter cells

7.1 LEARNING CHECK

- 1 What is a cell?
- 2 Who was the first person to see cells?
- 3 **Explain** how cells were first discovered.
- 4 Do you think the name 'cell' is appropriate? **Explain** your reasoning.
- 5 **State** the cell theory.
- 6 **Explain** how Schwann, Schleiden and Virchow built on the work of others to formulate the cell theory.
- 7 **Create** a timeline showing the development of the cell theory.

7.2 Cells

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ classify organisms as either unicellular or multicellular
- ✓ describe the difference between prokaryotic and eukaryotic cells.

GET THINKING

Skim through this module and look closely at the figures. Try to predict the difference between unicellular and multicellular organisms and prokaryotic and eukaryotic cells.

Unicellular or multicellular?

Living things that are made up of only one cell are called **unicellular**. In unicellular organisms, a single cell carries out all necessary life processes. Bacteria, amoeba, paramecium and yeast are examples of unicellular organisms (Figure 7.2.1a).

Many organisms are made up of more than one cell, and these organisms are called **multicellular**. Humans, animals and plants are examples of multicellular organisms (Figure 7.2.1b).

Although there are basic features that remain the same for all cells, the form of a cell changes depending on the organism in which it is found, and the job it does.



Video activity
The cell membrane

Interactive resource
Drag and drop:
Different types
of cells

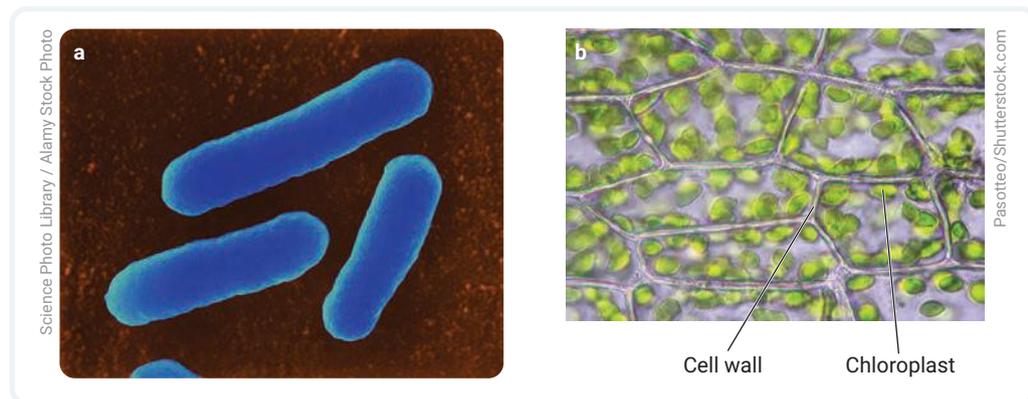
Extra science investigations
Effects of
surface area

Examining
plant cells

Modelling diffusion

micrometre (μm)

a unit of measurement equivalent to one-thousandth of a millimetre, or one-millionth of a metre



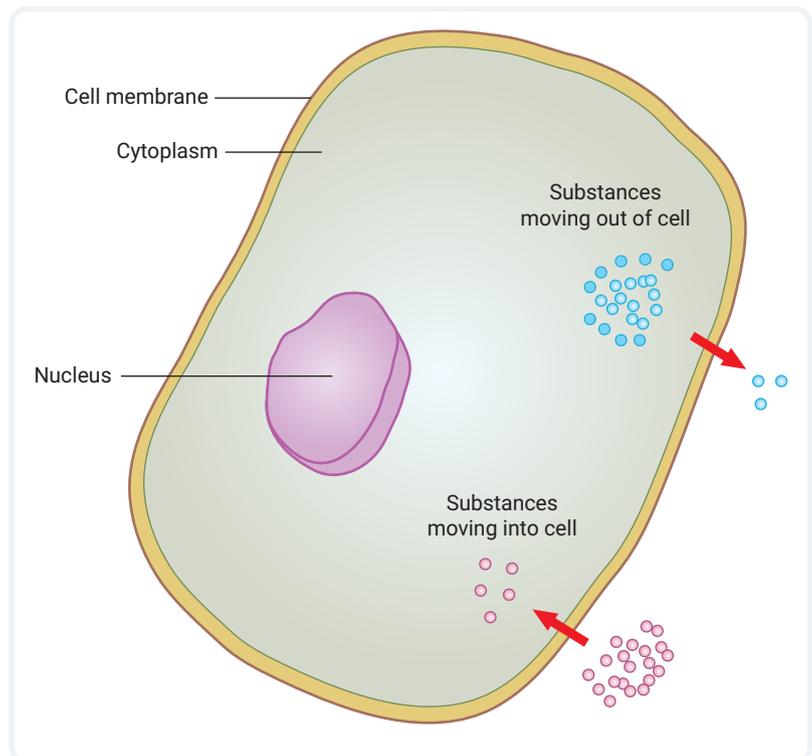
▲ FIGURE 7.2.1 (a) Unicellular bacteria; (b) leaf cells from a multicellular plant

The importance of being small

Most cells range from 10 to 100 **micrometres (μm)** in diameter, and in the previous module we saw that many cells are even smaller than this. There is a reason cells are so small. A cell receives all of its requirements through its cell membrane. It also passes all of its waste out through the cell membrane. Therefore, the surface area of the cell membrane is very important – it must be large enough to allow sufficient materials through and all wastes out, for the cell to function normally.

The cell membrane has tiny holes, or pores, that only allow small particles to move through it. These small particles move by **diffusion**. Diffusion is when a substance, such as water, sugar or oxygen, moves from a region of high **concentration** to a region of low concentration. This means a substance in high concentration inside a cell will tend to move through the cell membrane to the outside, where the substance is found in lower concentration. The reverse is also true. Substances that are in high concentrations outside a cell will move to the inside of the cell through the cell membrane.

When substances such as water, simple sugars and oxygen are used up by the cell, their concentration decreases. This means these substances are in higher concentrations outside the cell and will move through the cell membrane to the inside of the cell. Once in the cytoplasm inside the cell, they are used in various processes that produce wastes. The wastes diffuse out of the cell from a high to a low concentration (Figure 7.2.2). This process of diffusion limits the maximum possible size of cells. As cells get larger, there is less membrane surface area compared to the volume of the cell. If the surface area of the membrane is not sufficiently larger than the volume of the cell itself, the cell will not survive. Therefore, unicellular organisms are very small, while larger multicellular organisms contain many very small cells.



▲ **FIGURE 7.2.2** Substances diffuse through the cell membrane from areas of high concentration to areas of low concentration.

diffusion

the movement of particles from an area of high concentration to an area of low concentration

concentration

the amount of solute present in a specified amount of solution

Prokaryotes

Living things are classified according to whether their cells have a **nucleus**. Organisms whose cells have a simple structure and do not have a nucleus are called **prokaryotes** (pronounced 'pro-carry-oats'). All prokaryotes are unicellular, and they have no membrane-bound organelles. These organisms belong to kingdom Monera (also sometimes known as kingdom Bacteria and kingdom Archaeobacteria) (Figure 7.2.6, p. 261). Prokaryotes come in different shapes, from simple rod and spherical shapes to corkscrew spirals (Figure 7.2.3).

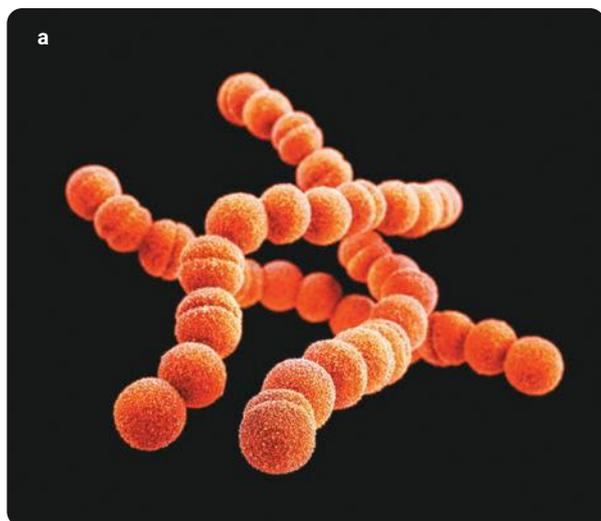
Although some bacteria cause disease, many bacteria do important jobs in your body and in everyday life. *Escherichia coli* (pronounced 'esh-e-reek-e-uh cole-eye', or 'E. coli' for short) lives in the intestines of humans and helps to keep your gut healthy. *Lactobacillus* and *Streptococcus* bacteria species are used to make yoghurt. Some yoghurt manufacturers add a second *Lactobacillus* strain, *Lactobacillus acidophilus*, which may have additional health benefits.

nucleus

the part of a cell that contains genetic material and is bound by the nuclear membrane

prokaryote

a unicellular organism without a nucleus



Science Photo Library / Alamy Stock Photo

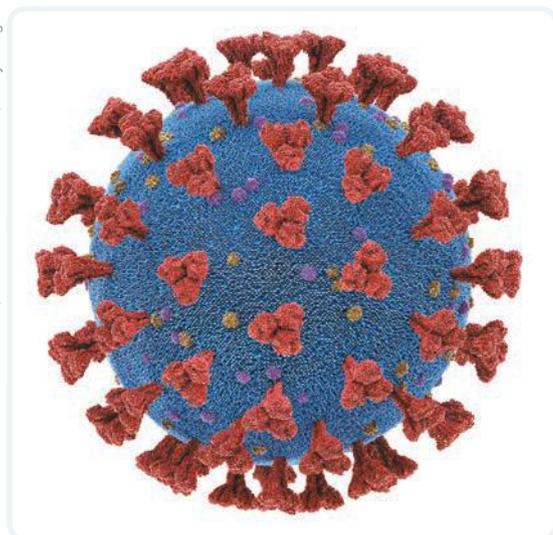


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Phantie - Sipa Press / Alamy Stock Photo

◀ **FIGURE 7.2.3** Examples of prokaryotes: (a) the spherical *Streptococcus pyogenes*, which causes a 'strep' sore throat; (b) the rod-shaped (bacillus) *Mycobacterium tuberculosis*, which causes the lung disease tuberculosis; and (c) the spirochaete *Treponoma pallidum*, which causes the disease syphilis



KTSDSIGN/SCIENCE PHOTO LIBRARY/Getty Images

▲ **FIGURE 7.2.4** A virus particle

eukaryote

an organism composed of one or more cells that contain a nucleus and membrane-bound structures

Viruses

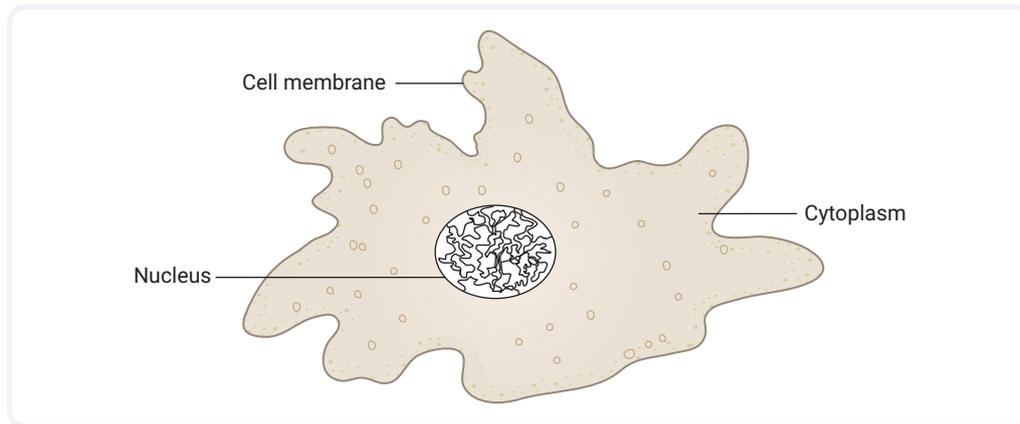
If cells are the basic subunits of all living things, where do viruses fit in? Viruses are not cells and are not classified as living things. They are much smaller than cells, ranging from 10 to 300 nanometres (nm) in diameter. Viruses do not have all the features of living organisms, such as feeding or respiration (Figure 7.2.4).

Eukaryotes

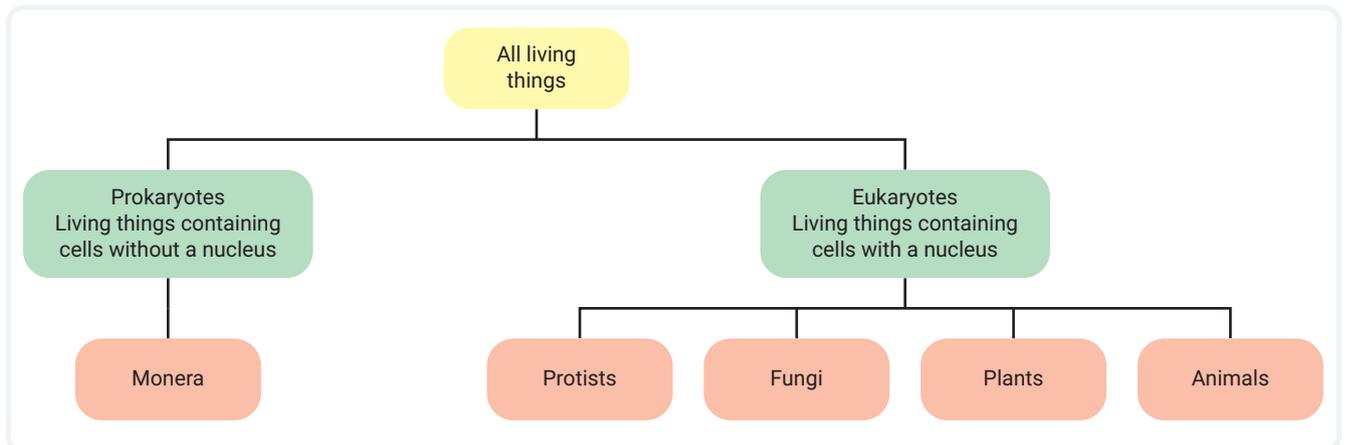
Eukaryotes (pronounced 'you-carry-oats') are organisms whose cells contain a nucleus and membrane-bound structures called organelles (Figure 7.2.5). While prokaryotic and eukaryotic cells have many features

in common, the cells of eukaryotes are larger and more complex than those of prokaryotes. The nucleus in eukaryotes is a membrane-bound organelle within the cell that keeps the nuclear material separate from the rest of the cytoplasm. Some other organelles in eukaryotes are also membrane-bound. Eukaryotes are classified

in the animal, plant, fungi and protist kingdoms (Figure 7.2.6). While all prokaryotes are unicellular, not all eukaryotes are multicellular. Protists and algae are examples of unicellular eukaryotes. Animals and plants are multicellular eukaryotes.



▲ FIGURE 7.2.5 A unicellular amoeba is a eukaryote because it contains a nucleus.



▲ FIGURE 7.2.6 Living things are classified according to whether their cells have a nucleus.

7.2 LEARNING CHECK

- 1 What do all prokaryotic cells have in common?
- 2 What two main features differentiate a eukaryotic cell from a prokaryotic cell?
- 3 What part of the cell forms the surface area of a cell?
- 4 **Explain** why oxygen diffuses into a cell and wastes diffuse out of a cell.
- 5 Is it true to say all prokaryotes are unicellular and all eukaryotes are multicellular? **Explain** your answer.
- 6 All bacteria are harmful. Is this statement true or false? **Explain** your answer.

7.3 Observing cells

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ identify and state the functions of the different parts of a microscope
- ✓ relate lens magnification to field of view
- ✓ relate the parts of a microscope to their function.

GET THINKING

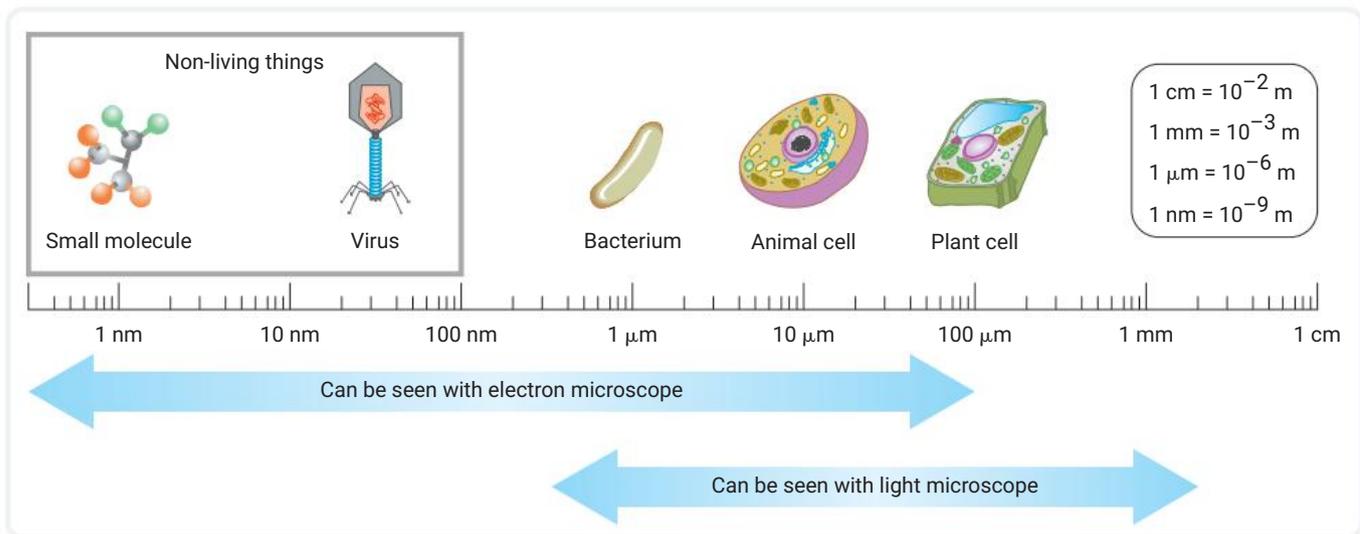
The cells in your body are like the rooms in a house. Think about this concept as you read the information in this module, and then try to explain it in your own words.

Size of cells

nanometre (nm)

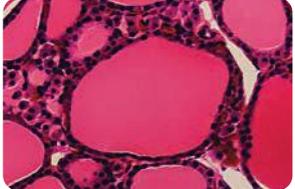
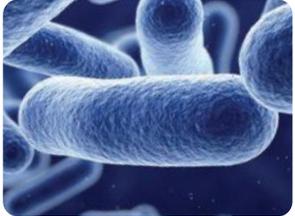
a unit of measurement equivalent to one-billionth of a metre

Cells are usually measured in micrometres (μm) (one-millionth of a metre). You cannot see this size with the unaided eye, so you need a microscope to see cells (Figure 7.3.1). There are many different cells of many different sizes. Table 7.3.1 shows the sizes of some cells. Smaller, non-living things, such as viruses, are measured in **nanometres (nm)** (one-billionth of a metre).



▲ FIGURE 7.3.1 The relative sizes of different cells

▼ TABLE 7.3.1 The different sizes of cells

Cell	Size	Cell	Size
Hen's egg	 30 mm (3 cm)	Animal cell	 10–100 μm
Large amoeba (a single-celled organism)	 800 μm (0.8 mm)	Spermatozoan	 7 μm
Human ovum (egg cell)	 100 μm	Bacterial cell	 1 μm
Plant cell	 100 μm		



Interactive resource
Label: Microscope

light microscope

a microscope that uses light to view the specimen

specimen

a sample to be examined or observed

Looking at cells: the light microscope

The most basic type of microscope is a **light microscope**, in which light passes through the **specimen**. It consists of a series of lenses that magnify the specimen and a light source at the base of the microscope. Look at Figure 7.3.2 and familiarise yourself with the parts of the light microscope shown. Learn their functions from the following information.



Thomas Söllner/EyeEm/Getty Images

▲ FIGURE 7.3.2 A light microscope

stage

a flat platform that supports the slide on a light microscope

objective lens

a lens on a microscope that receives light rays from the specimen and forms an image on the eyepiece

eyepiece lens

a lens on a microscope through which the eye views the image formed by the objective lens

field of view

the diameter of the circular area that appears when you look into a microscope

magnification

the action of enlarging the apparent size of a specimen being observed

The **stage** is a flat platform. This is where the slide is placed. It has a hole in the middle to allow light, from a light source, onto the specimen. The specimen is the sample that is being examined under the microscope. Stage clips hold the specimen slide firmly in place. In microscopes with a mechanical stage, the slide is moved by turning two knobs instead of the slide being moved manually. When a slide is moved right, because of the effect of the lenses in a microscope, it will appear to move left when viewed through the microscope. Similarly, if moved down, it will seem to move up.

The two main types of lenses on light microscopes are the **objective lens** and the **eyepiece lens** (or ocular lens). There are usually three or four objective lenses on a microscope. They consist of magnifying powers of 4×, 10×, 40× and 100×, with the most powerful lens being the longest. The eyepiece, or ocular lens, is what the user looks through to view the specimen. This usually magnifies the specimen by 10×.

The **field of view** of a microscope is the diameter of the circular area that appears when you look into a microscope. As you move to a higher **magnification**, the field of view becomes smaller because you are looking at a more magnified part, meaning you are ‘zooming in’ further and focusing on a smaller section of the specimen.

There are two different types of adjustment knobs: the **fine focus knob** and the **coarse focus knob**. They are used to focus the microscope on the specimen by raising and lowering the stage to be closer to or further away from the objective lens. Because the fine focus knob moves the stage more slowly than the coarse focus knob, it is used at higher magnifications.

The **iris diaphragm** is located under the stage of a microscope and its main function is to regulate the amount of light that passes through the specimen.

Magnification

Magnification is a measure of how much larger a specimen or part of the specimen appears. Both the eyepiece and objective of the microscope contain magnifying lenses. When you calculate the total magnification of the specimen, you must include the magnification of both lenses in the calculation.

$$\text{eyepiece lens magnification} \times \text{objective lens magnification} = \text{total magnification}$$

For example, if the eyepiece lens is 10 \times , and the objective lens is 10 \times , then the total magnification is 100 \times , which means the specimen will appear 100 times bigger than its actual size.

When you draw a biological specimen, it is important you note the total magnification you viewed the specimen at. This is so anyone else looking at your drawing will know how big the specimen is in real life.

Drawing cells viewed under the microscope

An important part of observing cells with a microscope is to accurately record your observations. Labelled scientific diagrams are the best way to record these observations. When drawing cells, there is a set of rules to follow to ensure your diagram is accurate.

- Use a sharp pencil and draw single solid lines.
- Make the diagram big enough (around 5–7 cm) that it is easy to label.
- Draw the cell membrane as a single, solid line.
- Show the cell wall in plants as a separate line surrounding the outside of the cell membrane.
- Draw all the organelles you observe inside the cell membrane.
- Label each structure with a clear, straight line touching the structure that you want to indicate (do not use arrowhead lines).
- Avoid crossing label lines; instead, make them parallel to each other.
- Use colour or shading to distinguish between the different cell structures.
- Include the microscope magnification.

fine focus knob

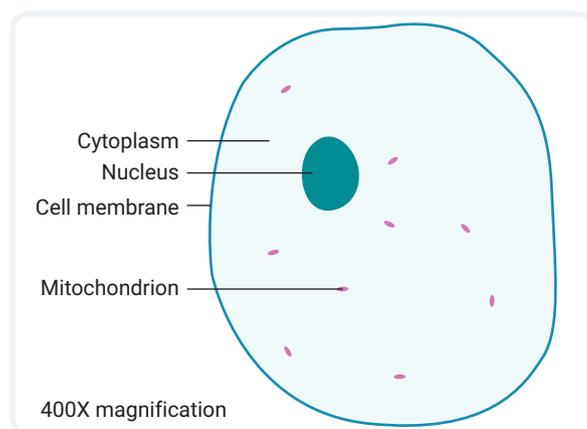
a knob that adjusts a microscope so that it focuses on the specimen by slowly raising and lowering the stage

coarse focus knob

a knob that adjusts a microscope so that it focuses on the specimen by rapidly raising and lowering the stage

iris diaphragm

a part of a microscope that regulates the amount of light that strikes the specimen



▲ FIGURE 7.3.3 A simple labelled drawing of a cell

Two microscopy techniques: making a wet mount and staining a specimen

wet mount

a glass slide that holds a specimen in a liquid such as water for viewing under a microscope

stain

a dye used to colour specimens for microscopic study

A **wet mount** is a glass slide that holds the specimen in water. This means you can look at live specimens without them drying out. Examples of specimens used in a wet mount are pond water, onion skin and thin slices of vegetable matter such as potato flesh.

A **stain**, such as iodine, can help you see the different parts of the specimen more clearly. Stains are able to enter the cell and highlight different components of the cell. This can help scientists better understand cell function.

To learn about preparing a wet mount slide and staining a specimen, refer to Module 7.8.

7.3 LEARNING CHECK

- 1 What unit of measurement is used to measure a cell? How big is this unit?
- 2 If a slide is moved down, in what direction will it appear to move when viewed through a microscope?
- 3 **Calculate** the:
 - a total magnification with a 10× eyepiece lens and a 40× objective lens.
 - b magnification of the eyepiece lens if the objective lens is 100× and the total magnification is 400×.
- 4 When a person changes the objective lens from 10× to 40×, will the field of view become smaller or larger?
- 5 What is the purpose of using a stain on a wet mount?
- 6 Why is water added to a wet mount?
- 7 **Compare** the functions of the fine focus and coarse focus, and **outline** when one or the other would be used.



Drawing microscope observations

SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ setting up and using a microscope
- ▶ using a microscope to examine and draw cells
- ▶ estimating the cell size based on the magnification
- ▶ drawing scientific diagrams of cells.

Remember these rules when drawing scientific diagrams:

- make the drawing detailed and clear
- label all the main features you observe
- ensure the label lines touch the section of the drawing you want to indicate
- always note the microscope magnification you used in your observations.



Video

Science skills in a minute:
Using a microscope

Science skills resource

Science skills in practice:
Using a microscope to examine cells

USING A LIGHT MICROSCOPE TO SEE AND DRAW CELLS

AIM

To view a prepared slide of human blood using a light microscope and draw a diagram of the cells observed

Safety

Carry the microscope with two hands and always use it on a level surface. Take care when using glass slides. Report any breakages to your teacher immediately.

MATERIALS AND EQUIPMENT

- prepared slide of a sample of human blood
- light microscope

PROCEDURE

- 1 Place the slide onto the microscope stage and secure it with stage clips. Using the 10× objective lens and the coarse focus knob, bring the image into focus. Start with the stage as close to the objective lens as possible, then slowly turn the coarse focus knob to move the stage away until the slide comes into focus.
- 2 Next, look at the slide using the 40× and 100× objective lenses. Start from the focused position using the previous lens. Remember to only use the fine focus knob to focus.
- 3 Identify the red and white blood cells. Your teacher will help you do this.
- 4 Make a biological drawing of the sample at 100×, showing the relative sizes of the red and white cells.

ANALYSIS

- 1 What problems did you encounter while using the light microscope?
- 2 What are the obvious differences between red and white blood cells?

7.5 Cell structures and processes

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ identify the common organelles in cells
- ✓ describe the function of common organelles
- ✓ identify the organelles that are involved in the process of photosynthesis and cellular respiration
- ✓ explain the process of photosynthesis and cellular respiration.



Video activity
Photosynthesis

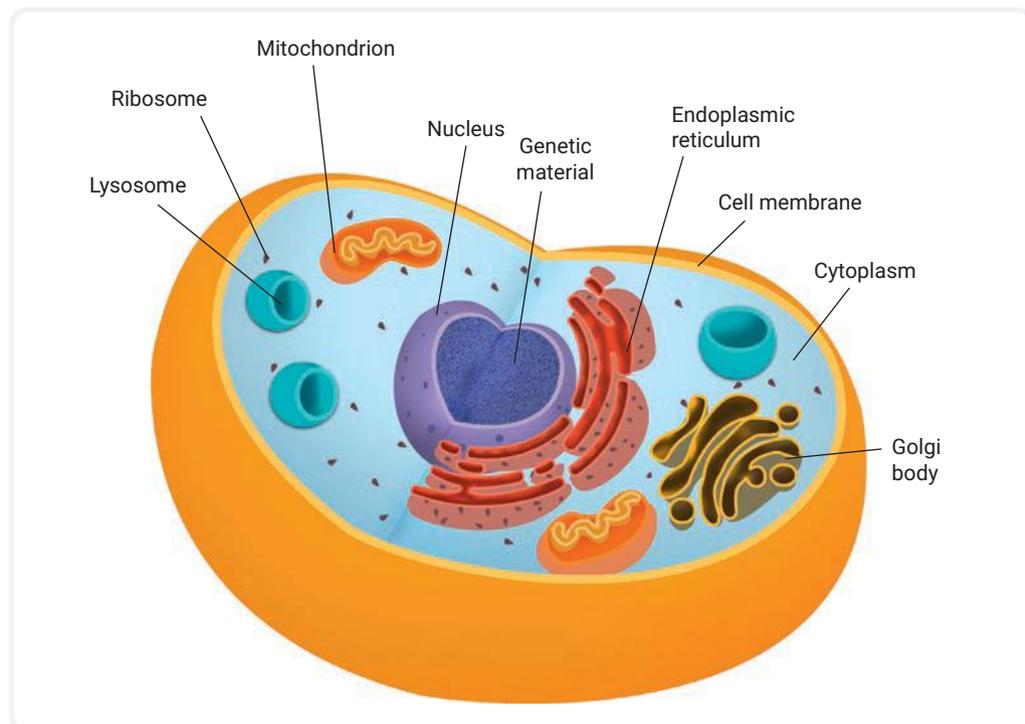
Interactive resource
Drag and drop:
Cellular respiration

GET THINKING

Cells may be tiny, but they carry out so many functions! Some of these functions are respiration, excretion, processing nutrients and creating new substances for our bodies. Using a town or city that you know, what areas of it could represent the cell parts that perform the functions listed above? For example, a bakery could represent the organelle that produces energy for your body.

Common structures in eukaryotic cells

Eukaryote cells have membrane-bound organelles inside them. Organelles are the small structures that carry out specific functions. The cells of eukaryotes – protists, fungi, animals and plant cells – have some key structures and organelles in common (Figure 7.5.1).



▲ FIGURE 7.5.1 Cellular structures common to all eukaryotic cells

Prince_Adur/Shutterstock.com

All cells are surrounded by the **cell membrane**. The membrane is the boundary between the interior of the cell and the outside environment. The inside of cells is filled with cytoplasm, a jelly-like substance that organelles float in. A summary of the main organelles and their functions are shown in Table 7.5.1.

▼ TABLE 7.5.1 Organelles and their functions

Organelle	Function
Cell membrane	Defines the cell boundary; regulates the movement of substances in and out of a cell
Cytoplasm	Jelly-like substance that organelles float in; fills the inside of a cell
Cytoskeleton	Gives shape and maintains internal structure of a cell
Rough endoplasmic reticulum (ER)	Involved in the synthesis of proteins; covered in ribosomes
Smooth endoplasmic reticulum (SER)	Synthesises lipids (fats); not covered in ribosomes
Ribosome	The smallest organelle; synthesises proteins
Golgi body	Processes and packages substances used in different cell functions
Mitochondrion	Produces a cell's energy during cellular respiration
Vacuole	Sac-like organelle filled with liquid; size and function vary, depending on the type of cell

cell membrane
the thin layer that forms the outer boundary of a living cell

rough endoplasmic reticulum (RER)
endoplasmic reticulum that produces and transports proteins

smooth endoplasmic reticulum (SER)
endoplasmic reticulum that transports and produces lipids and some carbohydrates

ribosome
an organelle that synthesises proteins; the smallest organelle

Golgi body
an organelle that processes, packages and stores proteins and lipids

mitochondrion
an organelle that generates chemical energy using cellular respiration

vacuole
a membrane-bound liquid sac found inside a cell

cellular respiration
a series of chemical reactions that break down glucose and release chemical energy

chemical reaction
a process that occurs when a substance changes to produce a new substance

Cellular processes

Cells need energy and nutrients to carry out their functions. The energy and nutrients are produced inside two organelles, the mitochondria and the chloroplasts.

Cellular respiration

Cellular respiration takes place in the mitochondria of all eukaryotic cells to produce energy for the cells. Cellular respiration is a series of **chemical reactions** that release energy from glucose, which is a simple sugar. Organisms need this energy to stay alive, grow, move and carry out all bodily functions. In cellular respiration, glucose and oxygen react to produce chemical energy, and the waste products carbon dioxide and water. All living things undergo cellular respiration. Cellular respiration can be summarised in a word equation (Figure 7.5.2).



▲ FIGURE 7.5.2 The word equation for cellular respiration

Photosynthesis

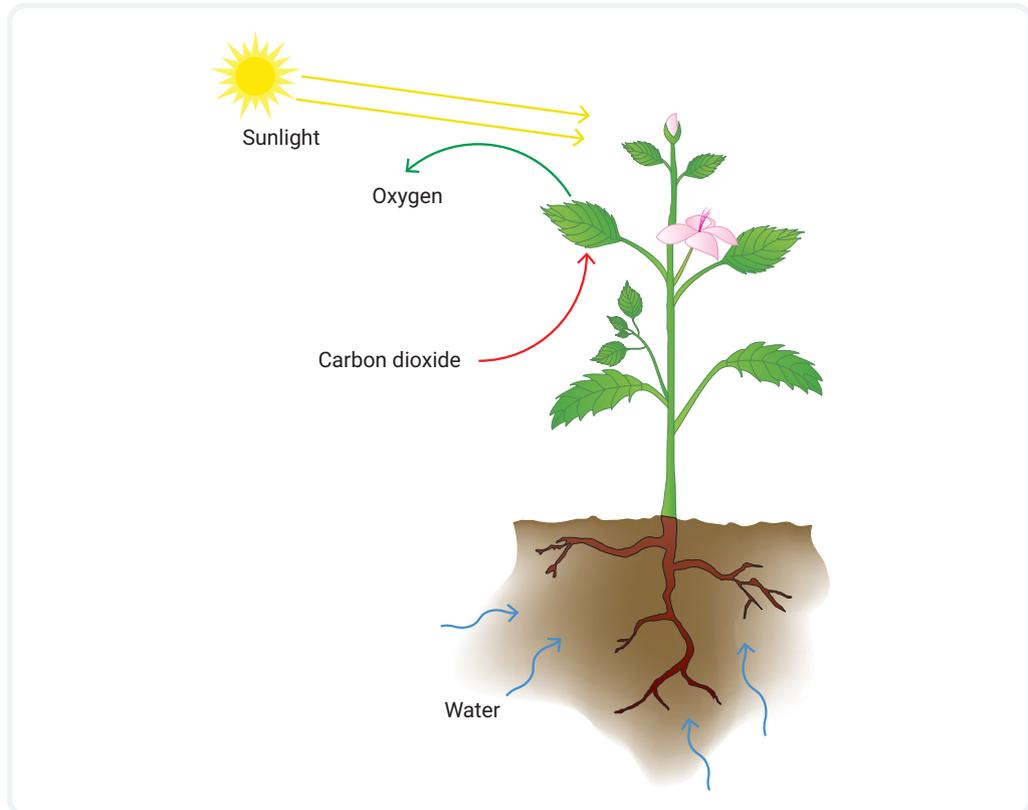
chloroplast

an organelle in plant cells that contains chlorophyll and carries out photosynthesis

chlorophyll

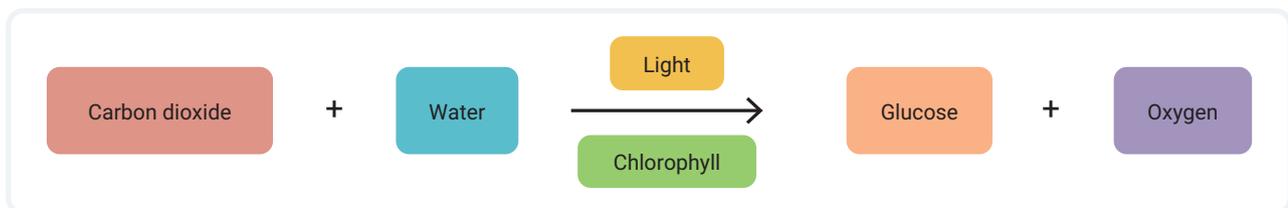
the green pigment in chloroplasts that absorbs light energy for photosynthesis

Chloroplasts are organelles found only in plant cells and the cells of some types of algae. The process of **photosynthesis** occurs in chloroplasts. Photosynthesis is a series of chemical reactions in which water (taken up by the roots of plants) and carbon dioxide (from the air) are converted into oxygen and glucose. Photosynthesis uses light energy from the Sun, which is absorbed by **chlorophyll** in the chloroplasts (Figure 7.5.3).



▲ FIGURE 7.5.3 The requirements for photosynthesis

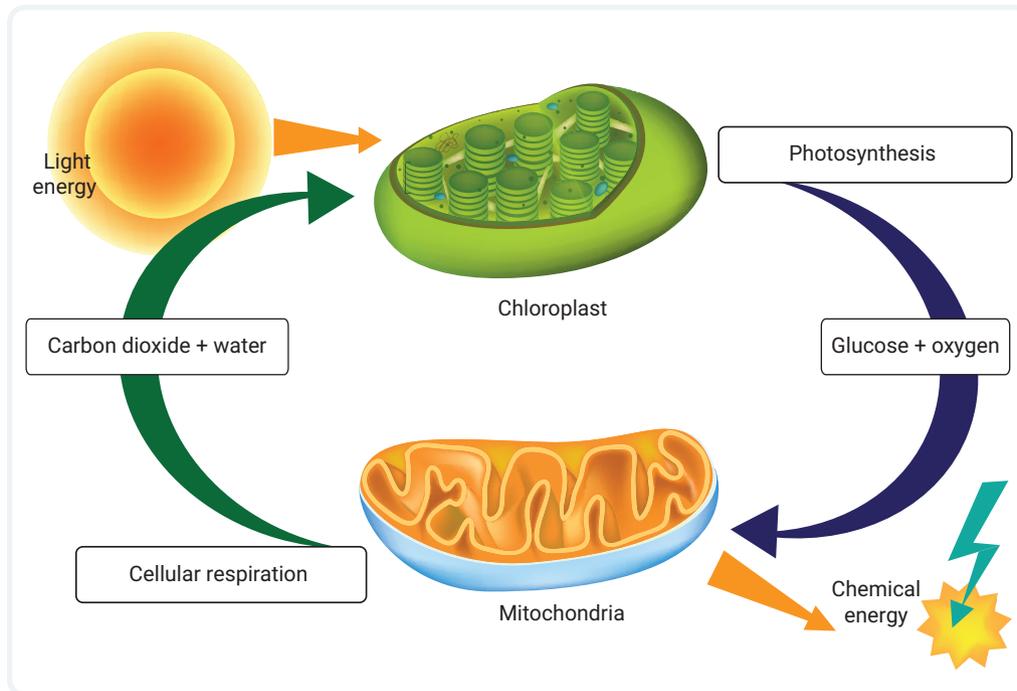
Photosynthesis can be summarised by the word equation shown in Figure 7.5.4.



▲ FIGURE 7.5.4 The word equation for photosynthesis

Relationship between cellular respiration and photosynthesis

Cellular respiration and photosynthesis are related to each other (Figure 7.5.5). The products of cellular respiration, carbon dioxide and water, are used in the process of photosynthesis. And the products of photosynthesis, oxygen and glucose, are used in the process of cellular respiration.



▲ FIGURE 7.5.5 The relationship between cellular respiration and photosynthesis

7.5 LEARNING CHECK

- 1 **Describe** the main function of the cell membrane.
- 2 Why is the cytoskeleton important in cells?
- 3 What is the relationship between the rough endoplasmic reticulum and the ribosomes?
- 4 **Explain** the importance of the mitochondria and the chloroplast in cells.
- 5 **Compare** and **contrast** the equations of cellular respiration and photosynthesis.
- 6 **Choose** your favourite organelle. **Research** who discovered it, and when and how it was discovered.

7.6 Animal cells

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ identify organelles in diagrams of animal cells
- ✓ describe the two organelles found only in animal cells: lysosomes and centrioles.



Interactive resources
Crossword:
Animal cells

Label: Animal cell

GET THINKING

Animal bodies are made up of millions of cells. Each cell contains organelles with specific functions. Investigate how many cells are in the human body compared with the number of cells in an insect, such as a fly. Does the size of the animal determine the number of cells? How many cells does an elephant have?

Cellular structures in animal cells

Animal cells have all the organelles and structures common to eukaryotic cells, as described in Module 7.5. Figure 7.6.1 shows the organelles in an animal cell.

There are two organelles found only in animal cells: lysosomes and centrioles.

Lysosomes are membrane-bound organelles containing digestive **enzymes**. Lysosomes break down large substances into smaller parts and function as the cell's waste disposal system (Figure 7.6.2a).

Centrioles are a pair of tube-like organelles, found near the nuclear membrane (Figure 7.6.2b). Centrioles help in the process of cell division. You will learn more about cell division in Stage 5 science.

lysosome

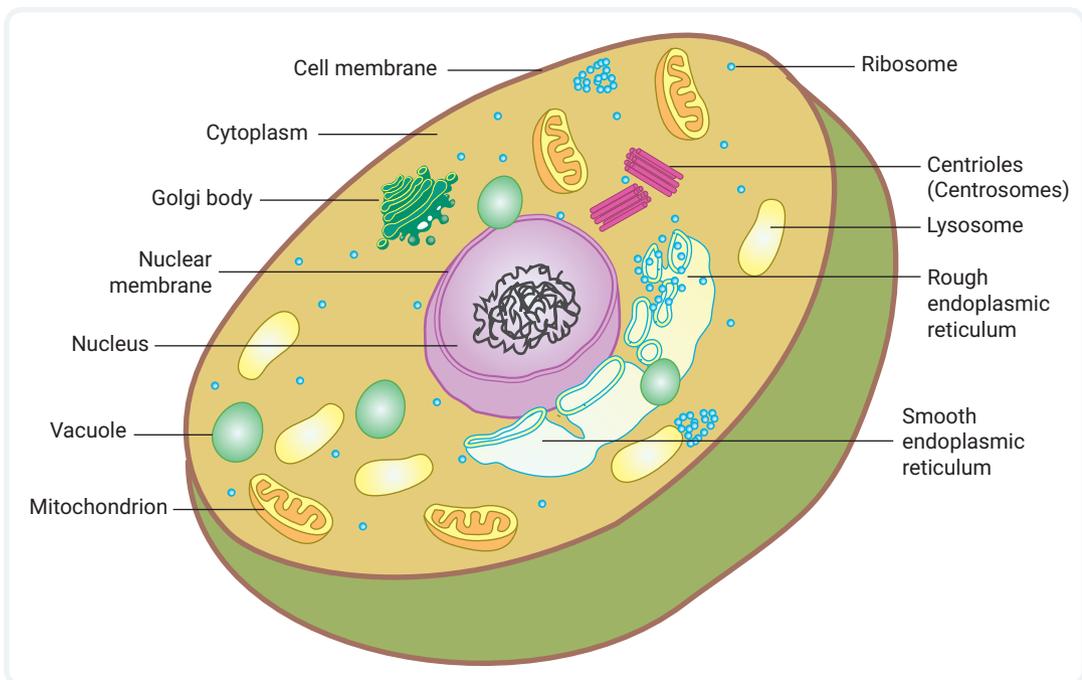
an organelle found in animal cells that breaks down and recycles old, worn-out cell organelles

enzyme

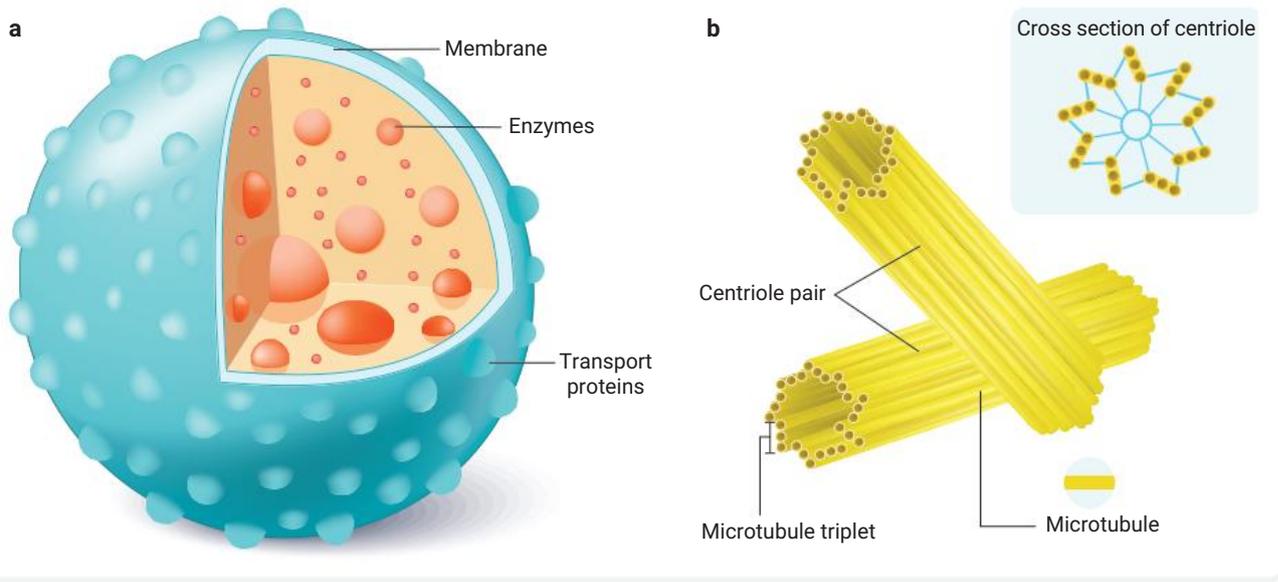
a protein found in the body that speeds up a chemical reaction

centriole

a tube-like structure found near the nucleus in animal cells that is involved in cell division



▲ FIGURE 7.6.1 A typical animal cell



▲ FIGURE 7.6.2 (a) Lysosomes and (b) centrioles are organelles found only in animal cells.

Making a model: The animal cell open sandwich

☆ ACTIVITY

Materials and equipment

- slice of bread
- knife
- jam (cytoplasm)
- chocolate biscuit (nucleus)
- poppy seeds (ribosomes)
- chocolate bits (small vacuoles)
- pieces of dried apricots skewered together with a toothpick (Golgi body)
- yellow lolly snakes sliced into thin strips (cell membrane)
- hundreds and thousands sprinkles (other organelles)

⚠ Safety

Food in the lab can be contaminated. Do not eat any of the materials in this model.

Procedure

Use the ingredients listed to construct an animal cell open sandwich. Look at the animal cell diagram (Figure 7.6.1) if you need help.

Analysis

- 1 **Evaluate** your model by describing its strengths and weaknesses.
- 2 **List** the extra ingredients you would use to create a plant cell sandwich. Share your list with the class.

7.6 LEARNING CHECK

- 1 **List** the common organelles in an animal cell.
- 2 **Draw** and label an animal cell.
- 3 **Describe** the two organelles that you would only find in animal cells.
- 4 **Write** a creative story to explain how the organelles function together in the animal cell. **Include** as many organelles as possible in your story.

DATA SCIENCE



Learn more about evaluating scientific models in **Module 2.10**.

7.7 Plant cells

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe the structure and function of key structures in plant cells.



Interactive resources

Drag and drop:
Plant cells

Label: Plant cell

GET THINKING

Imagine that you are eating a carrot. In what way do you think the plant cells in the carrot are different from the animal cells you learned about in the previous module?

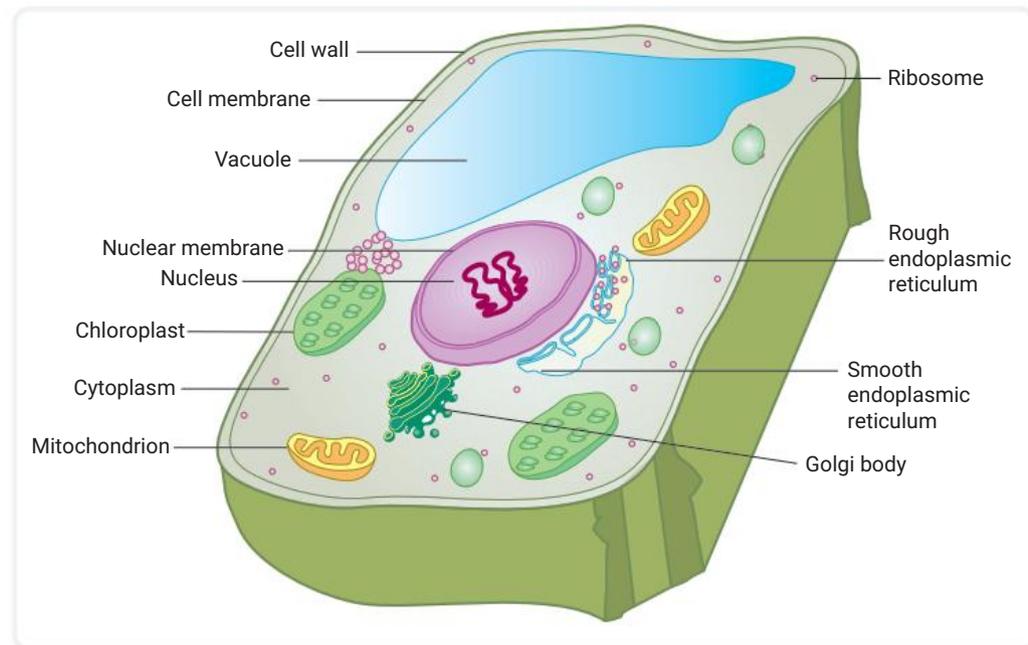
Plant cells and their structures

All plant cells have a similar cell structure (Figure 7.7.1). Plant cells contain the same structures as animal cells, including ribosomes, smooth and rough endoplasmic reticulum, Golgi bodies, mitochondria and a nucleus. These structures perform the same functions in plants as they do in animals.

Plant cells also have three additional structures not found in animal cells: chloroplasts, a large central vacuole (as opposed to numerous small vacuoles) and a **cell wall**.

cell wall

the rigid outer covering of plant cells that surrounds the cell membrane; made of cellulose



▲ FIGURE 7.7.1 A typical plant cell

Chloroplasts

Chloroplasts are clearly visible under the light microscope and occur in almost all plant cells that are exposed to light (Figure 7.7.2). The chloroplasts in plant cells are where photosynthesis takes place. They are green because they contain the pigment chlorophyll, which traps light energy. Photosynthesis transforms light energy into chemical energy that is stored in the glucose produced.

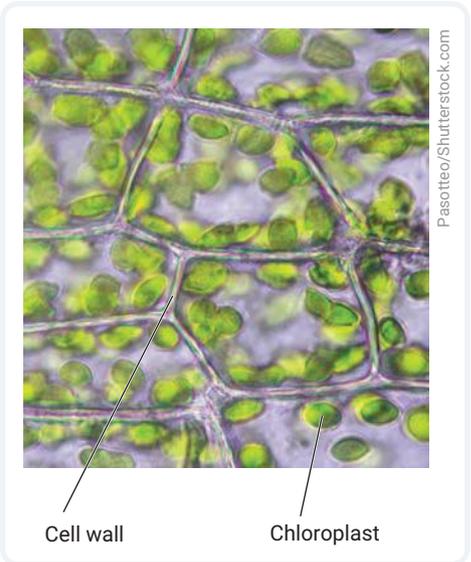
Large central vacuole

In plants, the large vacuole is a water-filled compartment surrounded by a membrane. It stores water and chemicals and provides support, maintaining the shape of the plant cell by holding water that pushes out against the cell wall. When all the cells in the plant do this, the plant can stand upright. But if the large central vacuoles are not full of water, the plant may wilt.

Cell wall

The cell wall is the rigid outer covering surrounding the cell membrane. It is made of cellulose. Cell walls give the plant cell shape and protection as well as strength and support. This function is important because, unlike animals, plants do not have a rigid skeleton or muscles that strengthen and support the body.

The functions of the three organelles that are only found in plant cells are summarised in Table 7.7.1.



▲ FIGURE 7.7.2 Cell walls and chloroplasts are clearly visible in these plant cells.

▼ TABLE 7.7.1 Summary of the functions of organelles found only in plants

Structure	Function
Large central vacuole	Stores water and chemicals
Cell wall	Rigid outer covering of a plant cell outside the cell membrane
Chloroplast	Site of photosynthesis where the plant uses light energy to convert carbon dioxide and water into glucose and oxygen

7.7 LEARNING CHECK

- 1 Describe** the function of the three structures found only in plant cells: chloroplasts, cell wall and large central vacuole.
- 2 Draw** and **label** a plant cell.
- 3 Compare** and **contrast** the structures and organelles in animal cells and plant cells.
- 4 Predict** whether it is possible to find a plant cell that does not contain chloroplasts. Explain your answer.
- 5** Which type of plant organelle, in your opinion, is the most important for a plant's survival? **Explain** your answer.



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ preparing a wet mount slide
- ▶ using stain and a microscope to observe cells.

PREPARING A WET MOUNT AND USING A STAIN TO OBSERVE PLANT CELLS

AIM

To prepare and look at your own slide of biological material and investigate the effect of using a stain to help you see the different parts of the cells

Safety

Take care when using a scalpel. Always cut away from yourself. Carry the scalpel in a tray with the point facing away from you. Never run when carrying a sharp object.

Always use a cutting board. Place the scalpel in the middle of the board so that it doesn't fall off the edge. Report any cuts to your teacher immediately.

Wash your hands after completing the activity. Clean up any iodine spills immediately.

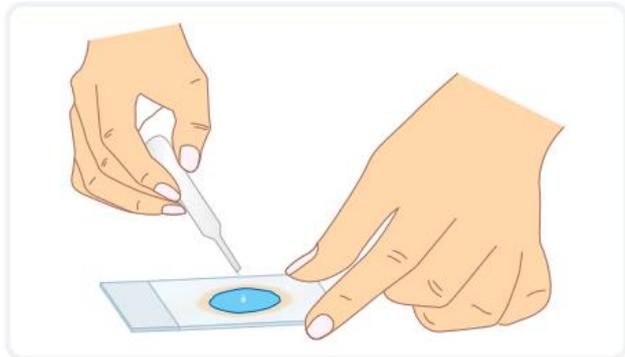
MATERIALS AND EQUIPMENT

- light microscope
- microscope slides
- coverslips
- eyedropper
- onion
- forceps
- scalpel
- cutting board
- iodine stain in a dropper bottle
- water
- paper towel

PROCEDURE

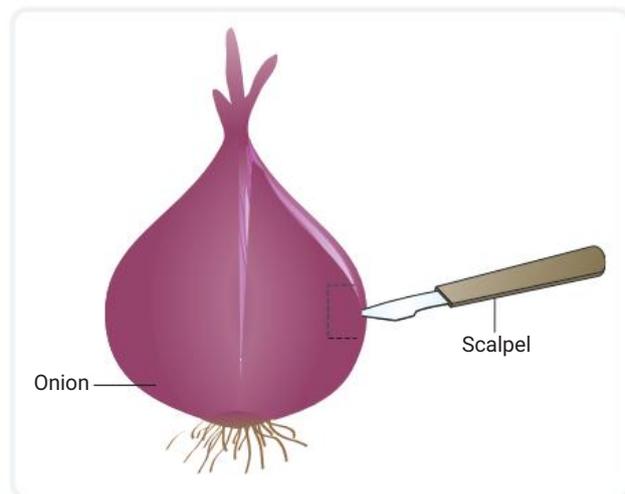
PART A: PREPARING THE SLIDE

- 1 Use the eyedropper to place one drop of water onto the middle of the microscope slide (Figure 7.8.1).



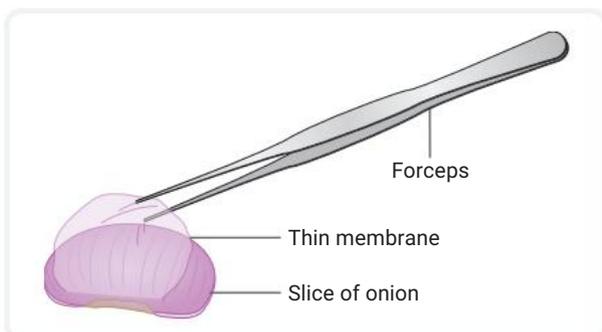
▲ **FIGURE 7.8.1** Place a drop of water onto the slide.

- 2 Use the scalpel to cut a small piece of onion (Figure 7.8.2).



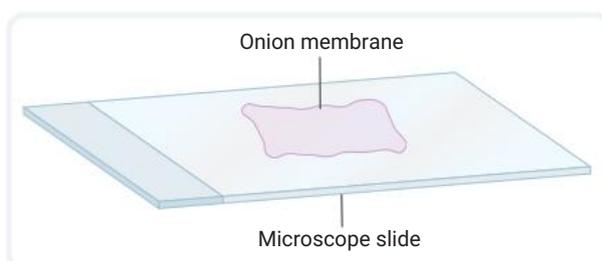
▲ **FIGURE 7.8.2** Cut a small piece of onion.

- 3 Use the forceps to peel a small piece of thin membrane from the onion (Figure 7.8.3).



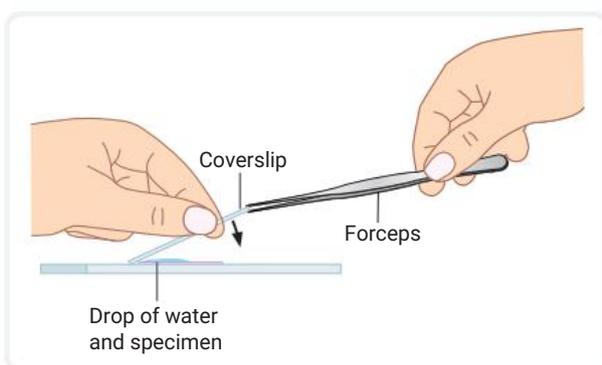
▲ FIGURE 7.8.3 Peel a piece of membrane from the onion.

- 4 Lay the thin membrane flat on top of the drop of water on your slide (Figure 7.8.4).



▲ FIGURE 7.8.4 Lay the membrane onto the drop of water.

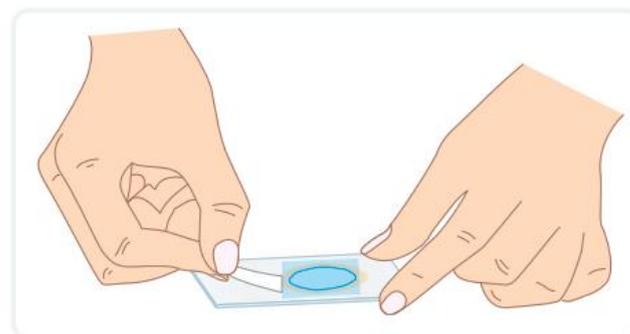
- 5 Carefully lower the coverslip. To do this without trapping air bubbles underneath it, you need to place one end of the coverslip so it rests on the slide at the edge of the water drop. Use the forceps to lower the other end of the coverslip onto the water drop and specimen as shown in Figure 7.8.5.



▲ FIGURE 7.8.5 Lower the coverslip onto the specimen.

PART B: VIEWING THE SLIDE

- 6 Place the slide onto the microscope stage and secure it with stage clips. Using the low power (10 \times) objective lens and the coarse focus knob, bring the image into focus.
- 7 Look at the slide using 40 \times and 100 \times objectives. Remember that, when you are using the 40 \times and 100 \times objectives, you will need to use the fine focus knob to focus.
- 8 Make a biological drawing of the sample at an appropriate magnification.
- 9 Use a stain to assist you in seeing the different parts of the onion cells more clearly. Place one drop of iodine stain at the edge of the coverslip. Place a piece of paper towel on the other side of the coverslip to draw the iodine stain under the coverslip, as shown in Figure 7.8.6.



▲ FIGURE 7.8.6 Draw the stain under the coverslip with a piece of paper towel.

- 10 Repeat steps 6–8 using the slide of stained cells.

ANALYSIS

- When making your own slide, what was challenging and what did you find easy?
- What did you see under the highest magnification?
- Record the differences and similarities you observed between an onion cell and a red blood cell (from Module 7.4).
- What structures could you distinguish within the cells?
- In what ways did the stain improve your ability to see parts of the cells?

CONCLUSION

What can you conclude about the value of microscopes in adding to your understanding of the structure of cells?

7.9 Specialised cells

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ explain why cells become specialised
- ✓ describe the relationship between the structure and function of a range of specialised cells.



Quiz
Specialised cells

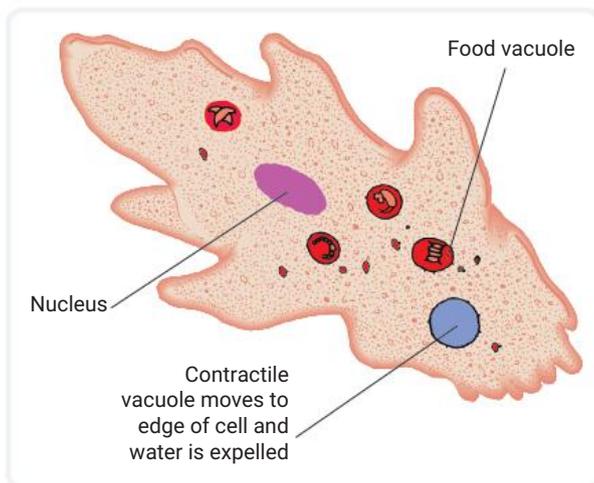
GET THINKING

Skim read this module, paying particular attention to the figures. Think about the range of specialised shapes and structures you can see in these cells. Note down a description of the most interesting ones.

Specialisations of unicellular organisms

Unicellular eukaryotic organisms have specialisations that allow them to live successfully in their environments. For example, to cope with living in fresh water, where water constantly diffuses through the membrane into the cytoplasm, an amoeba contains contractile vacuoles (Figure 7.9.1). These vacuoles gradually fill with water and, when stretched to a certain point, they contract, expelling the water from the cell.

The amoeba also has a very flexible cell membrane that makes finger-like temporary extensions of its cytoplasm. This allows it to move by flowing across the surface of rocks and mud, and lets it surround its prey. Figure 7.9.2 shows an amoeba sending out projections of its cell membrane to feed on a smaller organism. After the amoeba takes in the smaller organism, a food vacuole is formed in the cytoplasm. Enzymes within the food vacuole gradually digest the prey and any wastes are excreted out of the cell from the same vacuole.



▲ FIGURE 7.9.1 An amoeba with food vacuoles and contractile vacuoles

Science Photo Library / Alamy Stock Photo



▲ FIGURE 7.9.2 An amoeba surrounding its prey before engulfing it

Specialised cells in multicellular animals

In multicellular animals, a process called **differentiation** leads to specialised cells having cellular structures and contents that allow them to carry out a specific function. The size, shape and chemical composition of a cell often change during differentiation.

differentiation

a biological process whereby cells of an organism become specialised

Specialised animal cells

We saw in Module 7.6 that animal cells consist of a cell membrane surrounding cytoplasm in which a nucleus, mitochondria and other organelles occur. In most animal cells, this basic plan is modified to enable the cell to carry out a specific function. For example, fat cells are specialised as they contain a single large vacuole to store lipids for energy. The muscle cells in your heart are long and thin and contain fibres that can contract and cause your heart to beat. Muscle cells contain very large numbers of mitochondria. These carry out cellular respiration to provide energy for muscle contraction.

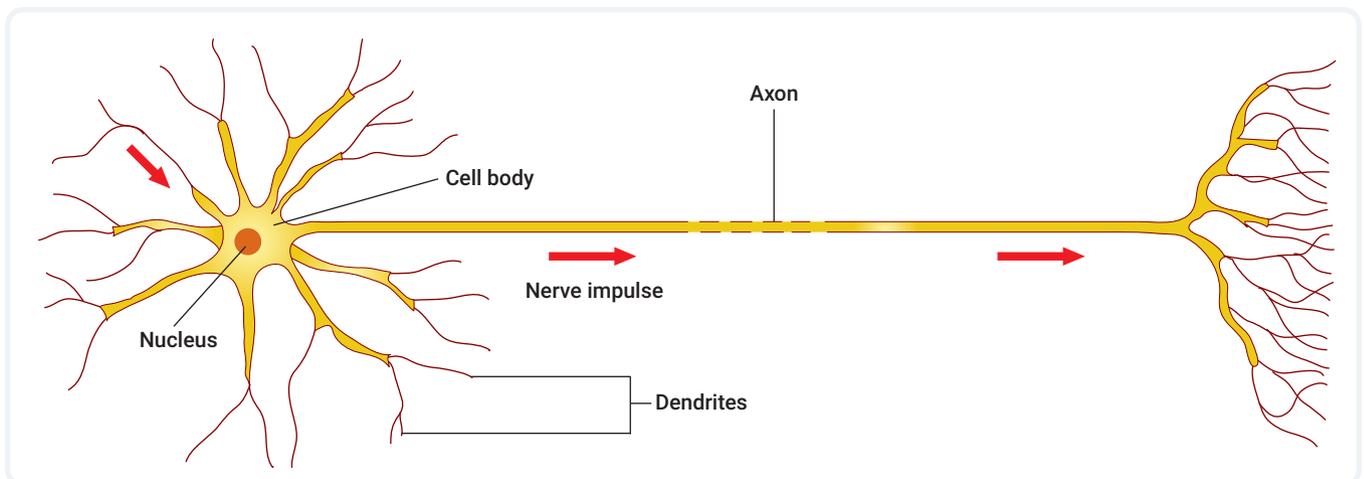
Neurons, or nerve cells, are the cells of the nervous system that carry messages to and from different parts of the body (Figure 7.9.3). Each neuron has a very long **axon**, or projection, from the cell body along which nerve impulses are transmitted. The axons that carry messages between your spine and feet are more than one metre long. Their branched connections at each end allow them to connect with other neurons.

neuron

a nerve cell

axon

the part of a neuron that carries the nerve impulse



▲ FIGURE 7.9.3 A neuron with a cell body and an axon

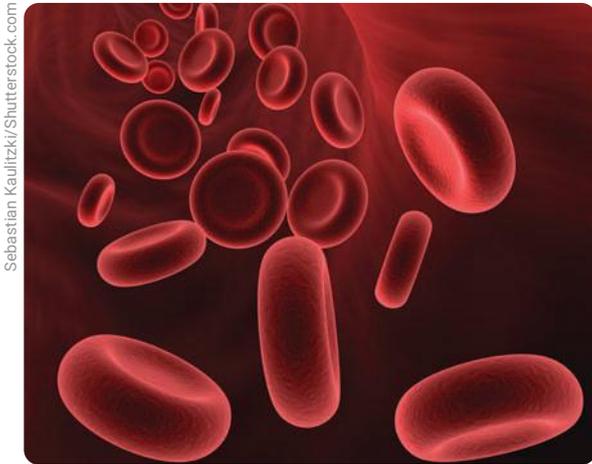
Red blood cells are highly specialised cells that carry oxygen around the body in the blood. They are packed with haemoglobin, which carries oxygen molecules. During differentiation, all their organelles, including the nucleus, are expelled from the cells to provide space for the haemoglobin. Their shape, like flattened discs with dips on both sides, is called **biconcave** (Figure 7.9.4). This shape provides a large surface area for the absorption of oxygen in the lungs. Red blood cells live for only 120 days. Old and damaged red blood cells end up in the liver, where they are broken down by white blood cells so they can recycle their components.

biconcave

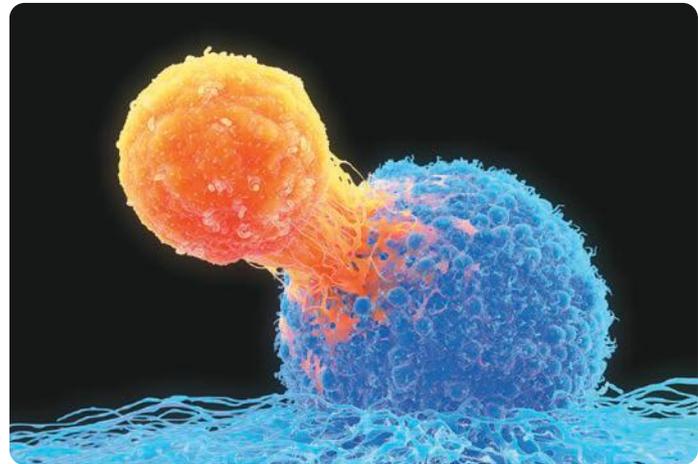
shaped like a flattened disc with dips on both sides

Another type of cell in blood is white blood cells. There are many different types of white blood cells. All help defend the body against disease. Some, like the white blood cell in Figure 7.9.5, are responsible for the detection and destruction of invading **micro-organisms**. Their cell membrane contains a system of recognition receptors to detect bacteria and dead body cells. The membrane forms long, thin extensions from the main cell body. These can attach to foreign cells, such as cancer cells, which can be surrounded and destroyed.

micro-organism
a very small living thing, only visible with a microscope



▲ FIGURE 7.9.4 Red blood cells have a biconcave shape.

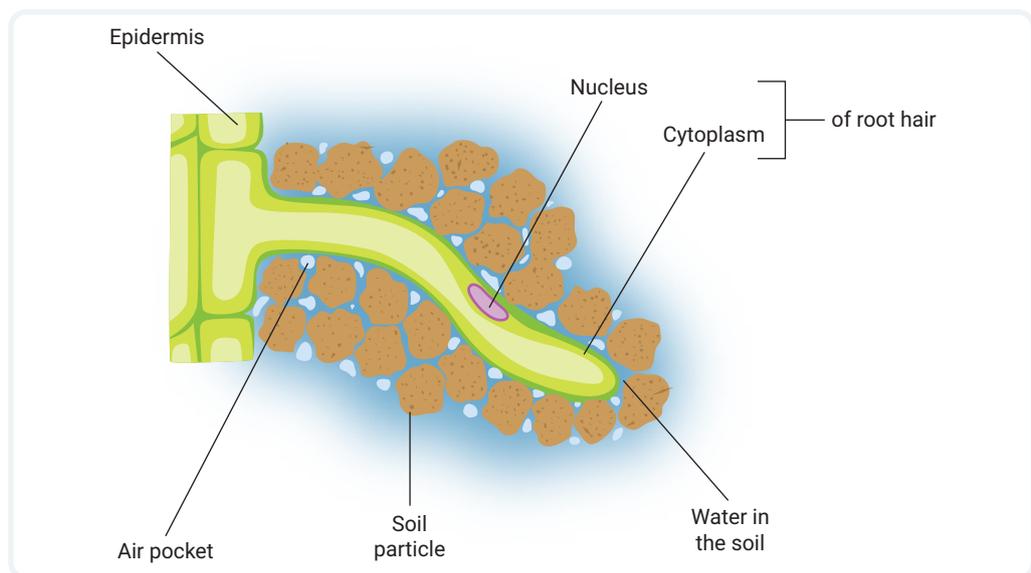


▲ FIGURE 7.9.5 A white blood cell using long extensions to attach to a cancer cell (coloured blue)

Specialised plant cells

Plants, too, have specialised cells that perform special functions. Roots absorb water from the soil for use by other parts of the plant. Figure 7.9.6 shows a cytoplasmic projection, called a **root hair**, from the surface of the root cell into the soil. Thousands of root hairs, just behind the root tip, provide an enormous surface area for water absorption.

root hair
a long extension that provides a large surface area for the root of a plant

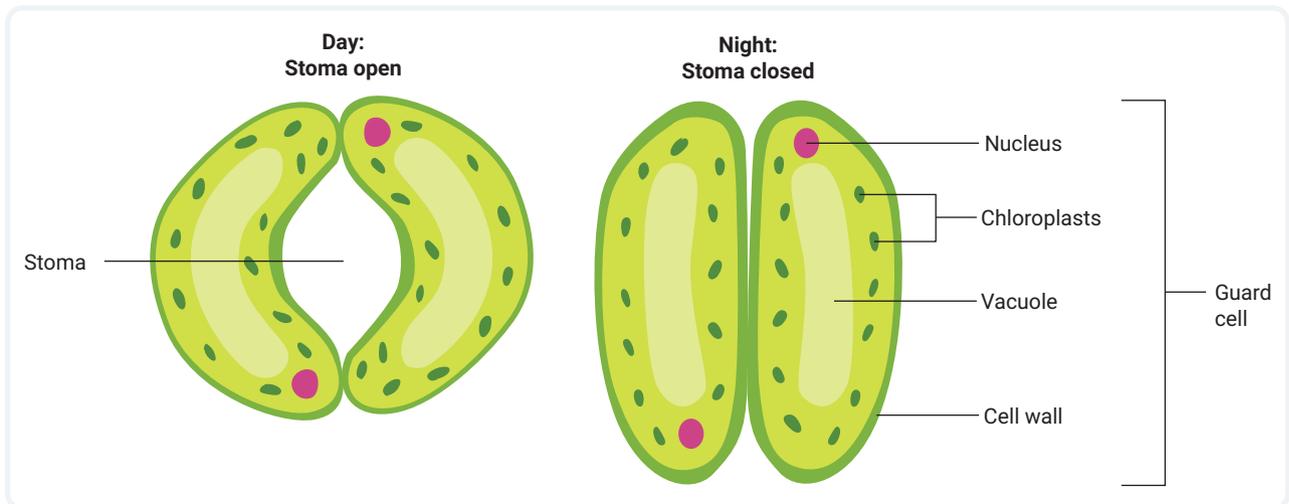


▲ FIGURE 7.9.6 A root hair cell

Guard cells are specialised crescent-shaped cells on the surface of leaves. They are arranged in pairs and form a small pore on the leaf surface. These pores, called **stomata** (singular: stoma), allow gases such as carbon dioxide and oxygen to enter and leave the leaf by diffusion. These gases are essential for photosynthesis and cellular respiration by plant cells. Guard cells can regulate the amount of water loss from a leaf, such as during hot days or at night, by changing their shape and causing the stomata to close (Figure 7.9.7). Guard cells contain significant numbers of chloroplasts.

guard cells
paired cells that surround the stomata of a plant, allowing them to open and close

stomata
pores on the surfaces of leaves that allow gas exchange (singular: stoma)



▲ FIGURE 7.9.7 A stoma, formed by a pair of guard cells that cause the stoma to open during the day and close at night

You will learn more about plant root hairs, stomata and guard cells in Chapter 12.

7.9 LEARNING CHECK

- 1 **Define** specialised cell.
- 2 **Describe** two specialisations of an amoeba.
- 3 **State** the function of a guard cell and describe how it is specialised to carry out this function.
- 4 **Describe** two specialisations of nerve cells and relate these to their function.
- 5 **Explain** why some cells are specialised.
- 6 Red blood cells only live for 120 days. What are the implications of this for:
 - a a blood donor?
 - b a blood donor recipient?
 - c the blood bank?

7.10 Specialised cells in tissues and organs

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe the hierarchy organisation between cells, tissues, organs, systems and organisms
- ✓ explain why multicellular organisms have multiple systems that work together.



Quiz
Levels of
organisation

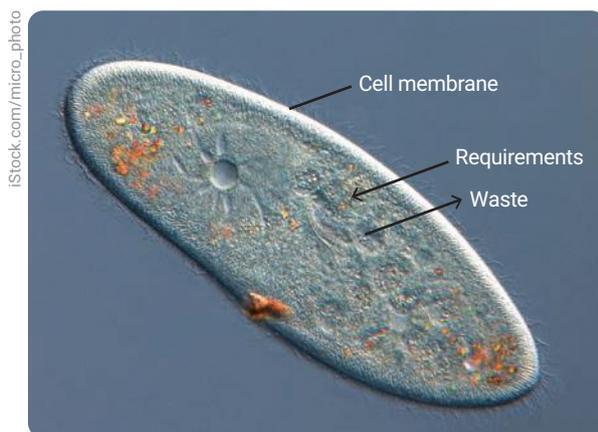
GET THINKING

All complex multicellular organisms have organs in their body. How many organs are in your body? How can you organise them into systems that group them together? Infer why organs are organised this way.

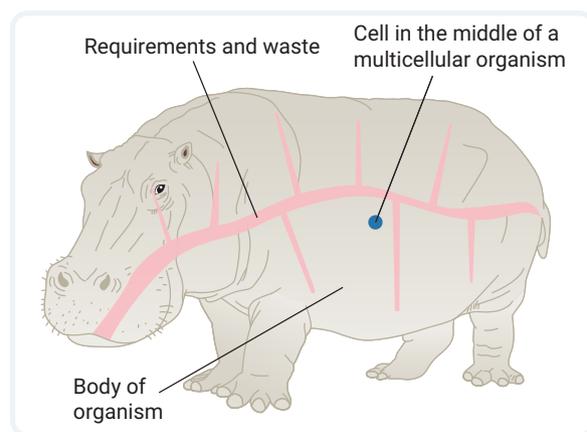
Too big for diffusion

In Module 7.2, you learned that cells rely on diffusion to obtain their requirements and get rid of waste. This is an ideal arrangement for unicellular organisms because they are small and their surface area (cell membrane) is exposed to the outside environment. Oxygen and nutrients easily diffuse across the cell membrane from the outside environment. Waste, such as carbon dioxide, easily diffuses out of the cell into the environment (Figure 7.10.1).

Multicellular organisms are made up of hundreds, millions and sometimes trillions of cells. Imagine a big ball of one trillion cells. How would the cell in the middle of the ball obtain oxygen or nutrients? If it relied on diffusion alone, it would die. The only way for the cell in the middle of the ball to survive is if oxygen and nutrients are brought to it and waste is removed. This is what your respiratory, circulatory, digestive and excretory systems do. These body systems use a network of pipes and tubes (such as arteries and veins) to connect all the cells. The pipes and tubes bring all body cells their requirements and remove their waste (Figure 7.10.2).



▲ FIGURE 7.10.1 Unicellular organisms, such as this *Paramecium*, can easily obtain their requirements and get rid of waste by diffusion across the cell membrane.



▲ FIGURE 7.10.2 Multicellular organisms have a system of pipes and tubes to provide all cells with their requirements and to remove their waste.

tissue

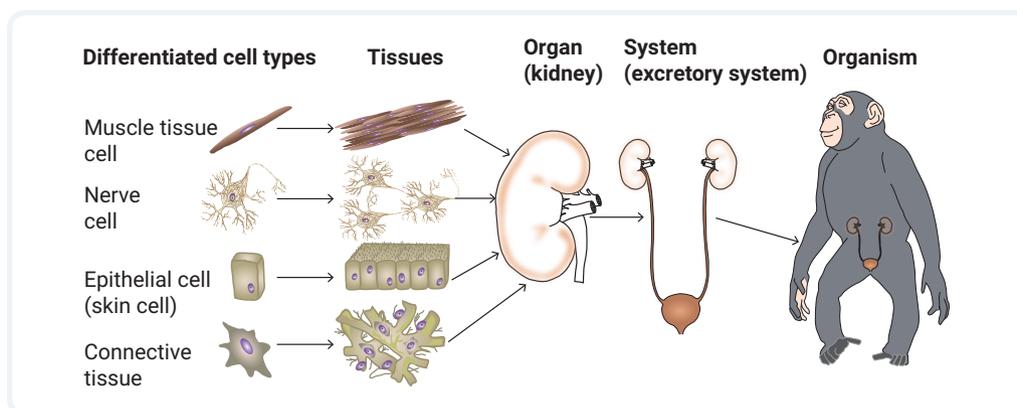
a collection of cells that have similar structures and functions

organ

a collection of different tissues that combine to perform a specific function

Levels of organisation: cells, tissues, organs and systems

Cells are the basic unit of all living things. A collection of cells that perform a similar function is called a **tissue**. For example, your skin cells form skin tissue. An **organ** consists of different tissues that carry out a particular function. For example, your



▲ FIGURE 7.10.3 Cells make up tissues; tissues make up organs; organs make up body systems.

kidneys are organs made up of a variety of different sorts of tissues, such as muscle and connective tissues. These tissues act together to achieve a common goal. When multiple organs are grouped together to carry out a specific function, this is called a **system** (Figure 7.10.3). Table 7.10.1 summarises the major organ systems of the human body.

system

a group of organs that work together to perform a specific function

▼ TABLE 7.10.1 Human organ systems

Organ system	Major organs	Major functions
Digestive	<ul style="list-style-type: none"> • Mouth • Oesophagus • Stomach • Intestines • Liver • Pancreas 	<ul style="list-style-type: none"> • Physical and chemical breakdown of food • Absorption of nutrients
Respiratory	<ul style="list-style-type: none"> • Lungs • Trachea • Bronchi • Bronchioles 	<ul style="list-style-type: none"> • Gas exchange
Circulatory	<ul style="list-style-type: none"> • Heart • Blood vessels (arteries, veins) 	<ul style="list-style-type: none"> • Transportation of nutrients, gases and waste • Transports cells that defend against infection
Excretory	<ul style="list-style-type: none"> • Kidneys • Bladder • Ureter • Urethra 	<ul style="list-style-type: none"> • Removal of liquid waste • Water balance
Musculoskeletal	<ul style="list-style-type: none"> • Bones • Muscles 	<ul style="list-style-type: none"> • Movement and support of body parts
Nervous	<ul style="list-style-type: none"> • Brain • Spinal cord 	<ul style="list-style-type: none"> • Conduct messages around the body • Control of body activities

Each organ system contributes to the survival of the whole organism. Body systems work together and depend on each other. For example, the respiratory system rapidly delivers oxygen from the air to the circulatory system, which then transports the oxygen to cells in the body. You will learn about the systems in the human body in Chapter 11.

7.10 LEARNING CHECK

- 1 **Define** tissue.
- 2 **Describe** how cells, tissues, organs and body systems are related.
- 3 Using an example, **explain** the purpose of your body systems.
- 4 **Compare** how unicellular and multicellular organisms obtain their requirements.
- 5 **Discuss** the importance of cell specialisation to the function of an organ of your choice.



SCIENCE SKILLS IN FOCUS

**IN THIS MODULE, YOU WILL FOCUS ON
LEARNING AND IMPROVING THESE SKILLS:**

- ▶ setting up and using a microscope
- ▶ using a microscope to examine and draw cells, showing specialised cell structures
- ▶ producing a simple science poster to present the results from a science investigation.

What is a science poster?

A science poster is like a visual mini-version of a science report. Posters usually contain images such as graphs, photos or diagrams, and not too many words.

What are science posters used for?

Scientists usually make posters as a concise way to share their science research or data with other scientists.

What information does a science poster have?

Science posters usually have the same sections as a science report.

- **Title:** This is often the question you asked in your project or research.
- **Introduction:** State the problem you were trying to solve and the aims of the research.
- **Method:** Briefly explain the materials and the steps used.
- **Results:** Present the information you collected or the observations you made. Use photographs, graphs or drawings.
- **Analysis and conclusion:** Explain what your findings mean.
- **References:** Keep the list short.



Video

Science skills in a minute:
Science posters

Science skills resource

Science skills in practice:
Writing science posters

**OBSERVING SPECIALISED CELLS
UNDER THE MICROSCOPE**

AIM

To observe and distinguish specialised cell structures.

! Safety

Carry the microscope with two hands and always use it on a level surface. Take care when using glass slides. Report any breakages to your teacher immediately.

MATERIALS AND EQUIPMENT

- prepared slides of specialised cells: muscle cells, intestine, brain cells, blood cells, stomata, root cells
- if slides of specialised cells are not available, photographs of specialised cells
- light microscope

PROCEDURE

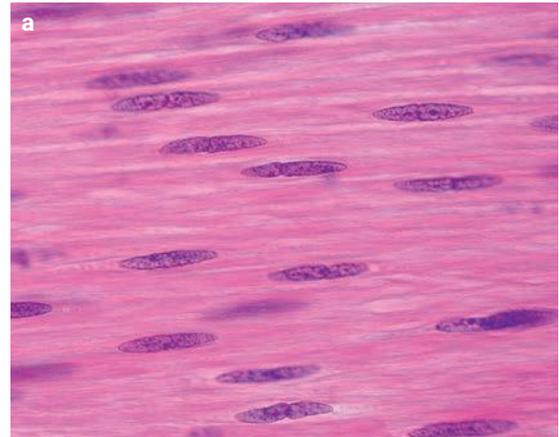
- 1 Place a slide of a type of specialised cells onto the microscope stage and secure it with stage clips.
- 2 Using the 10× objective lens and the coarse focus knob, slowly bring the image into focus. Start with the stage as close to the objective lens as possible, then slowly turn the coarse focus knob to move the stage away until the slide comes into focus.
- 3 Look at the slide using the 40× and 100× objective lenses. Start from the focused position using the previous lens. For these magnifications, use only the fine focus knob to focus.
- 4 Identify the cells and their specialised structures. Your teacher will help you do this.
- 5 Make a biological drawing of the sample at 100×, showing the relative sizes of the specialised cells and their structures. Remember to label your drawings and include the magnification.
- 6 If the structures are difficult to see, use photographs from the internet, or Figure 7.11.1.
- 7 Once you have drawn your cells and identified their structures, create your poster. Use the tips on the left to help you.

ANALYSIS

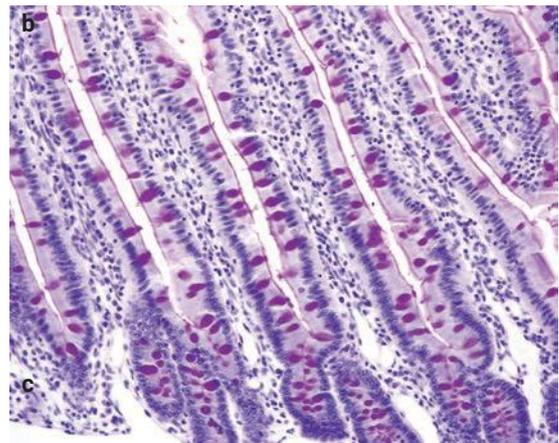
- 1 What problems did you encounter when you observed the specialised cells under the microscope?
- 2 What are the main differences that you observe between the different types of specialised cells? Create a table that illustrates those differences.

CONCLUSION

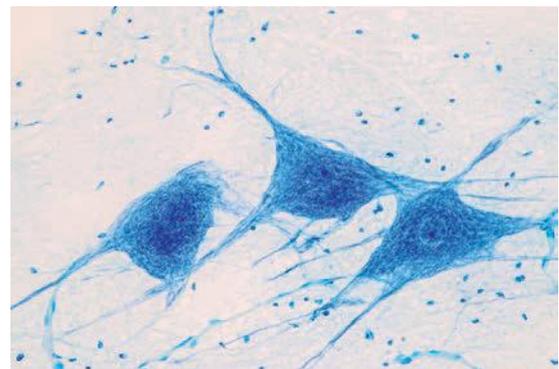
- 1 What can you conclude about observing specialised cells under the microscope? Were you able to distinguish all the features? Why?
- 2 How can you improve this investigation?
- 3 Remember to include a brief conclusion in your science poster.



Jose Luis Calvo/Shutterstock.com



Jlcalvo/Dreamstime LLC



Rattiya Thongdumhyu/Shutterstock.com

▲ **FIGURE 7.11.1** Images of specialised cells: (a) smooth muscle cells; (b) intestine cells; (c) neuron cells

7.12 Technological developments and improved understanding of cells

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ explain how the development of microscopes has led to an improved understanding of cells.

How do microscopes differ?

With the invention of the transmission electron microscope in 1931, the cytoplasm of cells, which previously looked to be without structure, was found to contain elaborate organelles. Both the light and electron microscopes have lenses and a stage that moves the specimen. However, it is the beam of **electrons**, instead of light, that provides a huge increase in magnification and **resolution** in the transmission electron microscope. Resolution is the ability of a microscope to distinguish detail. It is the ability to see two points individually, rather than merged.

The two images below show a human white blood cell. The light **micrograph** (Figure 7.12.1), taken with a light microscope, shows a fairly uniform, granular cytoplasm. By contrast, the electron micrograph (Figure 7.12.2), taken with a transmission electron microscope, clearly shows the nucleus, mitochondria and endoplasmic reticulum. Both images show the nucleus of the cell.

electron

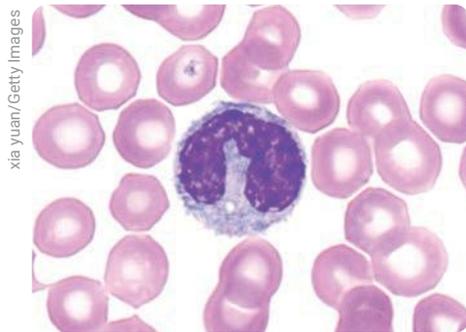
a negatively charged particle that moves in space around the nucleus of an atom

resolution

the finest detail that can be distinguished in an image

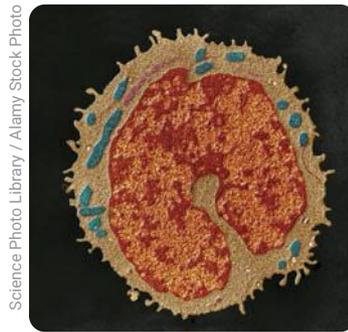
micrograph

a photograph taken using a microscope



xia yuan/Getty Images

▲ **FIGURE 7.12.1** A light micrograph of a human white blood cell surrounded by red blood cells



Science Photo Library / Alamy Stock Photo

▲ **FIGURE 7.12.2** An electron micrograph of a human white blood cell, showing the nucleus (red), mitochondria (blue) and endoplasmic reticulum (pink)

One disadvantage of the electron microscope is that it cannot be used to observe living cells because specimens are placed in a vacuum, mounted in plastic and sliced thinly so that the electron beam can penetrate the specimen.

7.12 LEARNING CHECK

- Describe** one way in which light and electron microscopes are:
 - similar.
 - different.
- Describe** the difference in resolution obtained by light and transmission electron microscopes.
- What type of microscope would you use to study the movement of a unicellular organism?
- Using microscopy as your example, **explain** how our modern understanding of cells has been linked to technological developments.

7 REVIEW

REMEMBERING

- 1 **Define** photosynthesis.
- 2 **State** the function of the fine focus knob of a microscope.
- 3 What is the role of the Golgi body in a cell?
- 4 **State** the function of lysosomes.
- 5 **Describe** three features common to eukaryotic cells.

UNDERSTANDING

- 6 **Explain** why cells were not known about until the 1660s.
- 7 **Name** the organelle that controls the functioning of eukaryotic cells.
- 8 **Explain** why stains are often used when preparing a wet mount slide.
- 9 **Explain** why cells are considered to be the basis of life.
- 10 **Explain** why a cell membrane is important to a cell.
- 11 **Explain** why you would expect a muscle cell to contain more mitochondria than a skin cell.
- 12 If plant cells can make their own nutrients, **explain** why they need mitochondria.

APPLYING

- 13 If you were given an unknown cell, **explain** how you would be able to tell whether it was:
 - a prokaryotic or eukaryotic.
 - b from a plant or an animal.
- 14 **Describe** the steps that you would carry out to make a wet mount slide of plant leaf cells.

ANALYSING

- 15 **Justify** why large organisms are multicellular.
- 16 **Compare** and **contrast** a plant leaf cell with a human muscle cell.
- 17 The structure of a guard cell is ideally suited to its function. **Provide** at least two reasons to support this statement.

EVALUATING

- 18 **a Evaluate** the role of bacteria in our world.
 - b **Conduct** a debate on the topic: Bacteria are an essential and necessary group of organisms.
- 19 A large cell of 0.3 mm was observed. Ribosomes were present in the cytoplasm, but no other organelles were visible. Could this be a prokaryotic or eukaryotic cell? **Justify** your answer. What other evidence would help you identify the cell?

CREATING

- 20 Use an online crossword generator to **create** a crossword for the eight parts of a light microscope.
- 21 **Imagine** you are interviewing Antonie van Leeuwenhoek or Robert Hooke. What are three questions you would ask?
- 22 You are given a spherical cell. **Describe** how you could redesign it so that it has a large surface area. Hint: Think about what shape your cell would have to be.
- 23 **Create** an argument to persuade your classmates that it is an advantage for eukaryotic cells to have different types of organelles.

SCIENCE IN DEPTH STUDY

#7

1 Connect what you've learned

In this chapter, you've learned that chloroplasts are organelles found in plant cells. You also learned that chloroplasts play an important role in the process of photosynthesis.

Create an infographic to display the information you have learned about chloroplasts.

2 Check your thinking

Research the theory that states that the chloroplast was an independent bacterium many millions of years ago that merged to become a part of a plant cell.

Explain the impact of this evolutionary change on our planet.

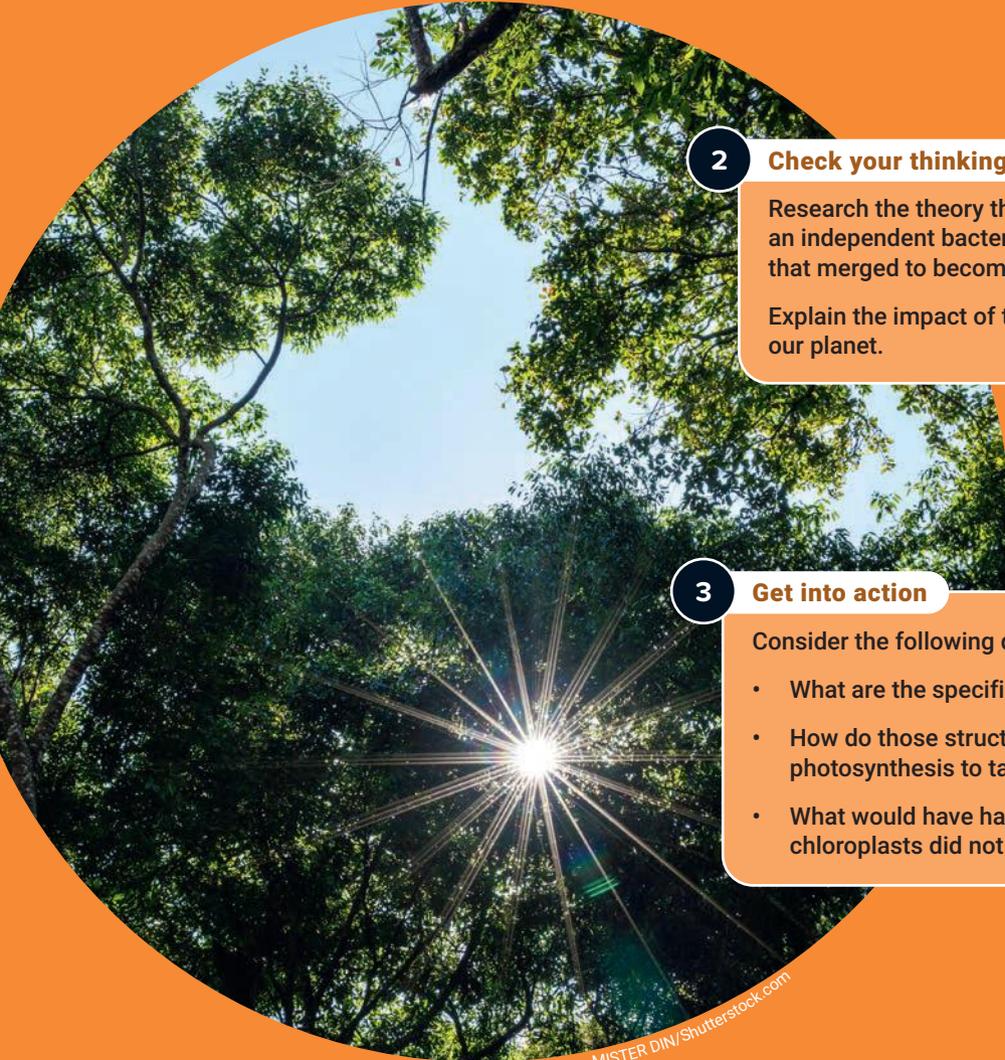
3 Get into action

Consider the following questions during your research.

- What are the specific characteristics of chloroplasts?
- How do those structural characteristics allow photosynthesis to take place in the organelle?
- What would have happened to life on Earth if chloroplasts did not exist?

4 Communicate

Use your knowledge and understanding to create a poster for a secondary school classroom that explains the structure and function of the chloroplast.



SOLUTIONS AND MIXTURES

SYLLABUS OUTCOMES

A STUDENT:

- ▶ explains how the properties of substances enable separation in a range of techniques SC4-SOL-01
- ▶ plans safe and valid investigations SC4-WS-03
- ▶ follows a planned procedure to undertake safe and valid investigations SC4-WS-04
- ▶ identifies problem-solving strategies and proposes solutions SC4-WS-07

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CHAPTERS RELATED TO THIS FOCUS AREA ARE:

- ▶ **CHAPTER 8** – PROPERTIES OF MATTER
- ▶ **CHAPTER 9** – MIXTURES
- ▶ **CHAPTER 10** – SEPARATING MIXTURES



Chris JG White/Shutterstock.com

8

Properties of matter

8.1 Matter (p. 292)

Matter is anything that has a mass and occupies space.

8.2 Particle theory of matter (p. 294)

Matter is made up of particles.

8.4 Properties of solids (p. 300)

The properties of a solid are due to the particles being held closely together and having limited movement.

8.3 States of matter (p. 296)

Matter can exist as a solid, a liquid or a gas.

8.5 Properties of liquids (p. 302)

The properties of a liquid are due to the particles being able to move past one another.

8.6 WORKING SCIENTIFICALLY: Measuring melting and boiling points (p. 304)

Melting and boiling points of water

8.8 Changing state (p. 308)

Matter will change state if enough energy is added or removed.

8.7 Properties of gases (p. 306)

The properties of a gas are due to the particles being as far apart as possible and moving quickly.

8.9 WORKING SCIENTIFICALLY: Evaluating an investigation (p. 312)

Melting points of matter

8.10 Properties of water (p. 314)

The density of materials can be determined by knowing their mass and volume. Buoyancy and surface tension are useful properties of water.

8.12 SCIENCE IN CONTEXT: The water cycle (p. 319)

Water is present near the surface of Earth in solid, liquid and gas forms. Water cycles through the environment in a series of processes.

8.11 WORKING SCIENTIFICALLY: Using an electronic scale (p. 317)

Density of water and common metals



Margaret Block West/Shutterstock.com

In the Arctic and Antarctic regions of Earth, there are places where ice is present all year round. In other places, the water freezes in winter and the ice melts in summer. In recent years, scientists have noticed that less ice has been forming and for shorter periods of time.

There are many animals that need the ice to exist so they can hunt their food, breed and survive in these extreme conditions. With less ice available for less time, some of these animals are suffering and may face extinction.

- ▶ Why does the water freeze and ice melt every year?
- ▶ Why might animals need the ice to survive?

▲ FIGURE 8.01 Melting sea ice affects the survival of wildlife.

#8 DIVE INTO SCIENCE!

At the end of this chapter, you can complete Science in Depth Study #8. You can use the information you learn in this chapter to complete the project.

Assessments

- Prior knowledge quiz
- Chapter review questions
- End-of-chapter test
- Depth study: Secondary sources investigation/poster

Videos

- Science skills in a minute: Accurate and valid results (8.9)
- Video activities: Solids, liquids and gases (8.3); Properties of gases (8.7); Changing states of matter (8.8); The water cycle (8.12)

Science skills resources

- Science skills in practice: Evaluating an investigation (8.9)
- Extra science investigations: Creeping oobleck (8.3); Particle movement in liquids (8.5)

Interactive resources

- Simulation: Introduction to gases (8.7); Phase changes (8.8); Density (8.10)
- Drag and drop: Describing matter (8.1); Solids v liquids (8.5)
- Crossword: Changing states (8.8)

8.1 Matter

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

✓ describe matter, including different examples.

GET THINKING

We take the things around us for granted, and don't think about what they are made of. Look around you. Can you think of a term that describes absolutely everything that you see?



Interactive resource
Drag and drop:
Describing matter

matter

anything that takes up space and has mass

What is matter?

When you look around you, it is easy to identify a wide range of different substances. If you were to list the substances within reach while you sit in your classroom, you could fill a page. There may be the top of the desk, paper, iPad, pen, water, other students, the air, the plastic of the seat, the metal of the frame of the desk or chair, the carpet ... and the list goes on! Although it may appear that all these things are different, they can actually all be classified as **matter**.



iStock.com/Riddofranz

▲ FIGURE 8.11 Matter is all around you.

mass

the amount of matter in an object, measured in kilograms (kg), grams (g) or milligrams (mg)

space

the three-dimensional region (length, width and height) where an object exists

Matter is defined as anything that has **mass** and occupies **space**. That sounds simple, but what does it actually mean?

Mass is a measure of the amount of substance, or matter, that makes up an object. In Chapter 3, you learned that we usually use an electronic balance to measure mass, and that it is measured in kilograms (kg), grams (g) or milligrams (mg). If we weighed a tennis ball and a baseball, the baseball would have a greater mass because it is made up of more matter.

Space is a three-dimensional region where things can exist. In other words, if something has a height, width and length, then it is occupying space.



Mark Fergus Photography

▲ FIGURE 8.1.2 The baseball has a greater mass than the tennis ball because it is made up of more matter.

Describing matter

As scientists, it is important that you can describe matter in such a way that other scientists will be able to identify the object. Therefore, we use **properties** that are consistent and clear so that there are no misunderstandings.

A property is a characteristic used to describe something by observation and/or measurement. Some common properties are colour, shape, texture, smell, flexibility, hardness, strength and dimensions.

The clearer and more specific the properties are, the more accurate the description will be. For example, describing something as a green solid could be confusing because the object could be broccoli, grass, a green box or a tennis ball. However, if you described it as a green, spherical solid of approximately 6.5 cm diameter with a soft, uneven texture, that could be squashed, and when it was dropped it returned to a similar height, then it is very likely to be a tennis ball.

property

a characteristic or feature of a substance

8.1 LEARNING CHECK

- 1 **List** the two properties exhibited by all matter.
- 2 **Explain** why a truck has a greater mass than a car.
- 3 Choose an item out of your pencil case and write a **description** using only its properties. Swap descriptions with a partner and see if you can identify each other's object.
- 4 **Suggest** some problems that might occur if scientists did not have a common language and understanding when describing matter.
- 5 Is air classified as matter? **Justify** your answer.

8.2 Particle theory of matter

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ state the particle theory of matter
- ✓ describe the structure of matter by applying the particle theory of matter.

GET THINKING

After reading this module, you will be asked to explain how the structure of matter is similar to students in a school. As you read the information, think about how the two things are similar.



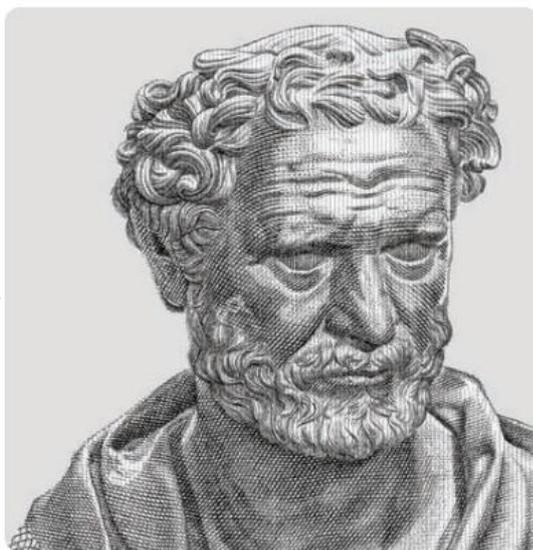
Quiz
What's the particle theory of matter?

Particle theory of matter

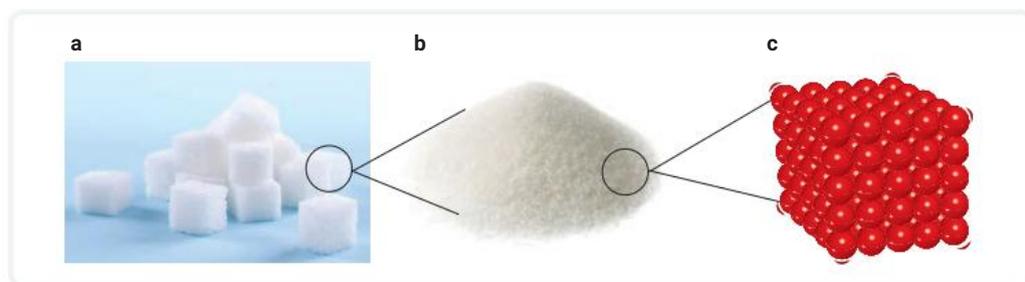
For a long time, scientists have tried to explain what matter is made of. As early as 2500 years ago, Greek philosopher Democritus developed a theory that stated that the universe consisted of empty space and an infinite number of particles. These particles were different from each other in form, position and arrangement. In the

19th century, English chemist John Dalton concluded that all matter was composed of a single, unique type of particle and that these particles could not be divided into smaller particles.

We now know that Democritus and Dalton were both right. Even though we can't see them, everything is made up of **particles**. For example, a cube of sugar might look like just one structure, but if you looked closely, you would see that it is made of smaller grains of sugar. If you could zoom in on the grains, you would see that they are made up of smaller units, which we call particles (Figure 8.2.2).



▲ FIGURE 8.2.1 Ancient Greek philosopher Democritus developed a theory about particles.



▲ FIGURE 8.2.2 (a) A sugar cube is made of (b) many grains of sugar, which are made of (c) particles.

particle
a tiny unit of matter

Prachaya Roekdeethaweesab/Shutterstock.com

These particles are too small for us to see, even with the most powerful electron microscope. Therefore, scientists developed a model to help us understand the structure of matter. This model is called the **particle theory of matter**. This theory states that matter is made up of particles that are in constant motion. The more energy the particles have, the faster they move and the further apart they are. Because the movement of the particles is related to their **kinetic energy** (the energy due to movement), this theory is also known as the kinetic theory of matter or the kinetic particle theory.

particle theory of matter

a theory that states that all matter is made up of particles that are in constant motion

kinetic energy

the energy of an object due to its motion

The particle model simulation

☆ ACTIVITY

Go to the PhET website and select the 'States of matter: Basics' simulation. Then click on 'States'.

- 1 Choose a type of atom or molecule.
- 2 Change the temperature to °C.
- 3 Press play.
- 4 Observe the movement of the particles.
- 5 Add heat and observe how the movement of the particles changes.
- 6 Remove heat by cooling and observe how the movement of the particles changes.
- 7 What is the lowest temperature that can be reached?

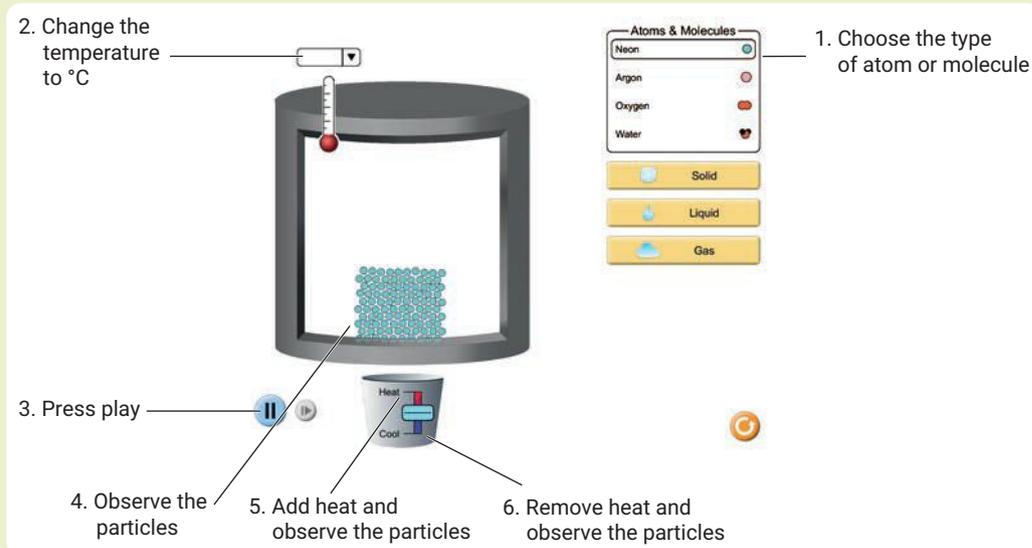


Image: PhET Interactive Simulations, University of Colorado Boulder, <https://phet.colorado.edu>



Weblink
PhET: States of matter

▲ FIGURE 8.2.3 The particle model simulation

8.2 LEARNING CHECK

- 1 **State** the particle theory of matter.
- 2 **Draw** a labelled diagram to show the structure of water in a beaker.
- 3 **Suggest** why other scientists might not have initially believed Democritus's explanation of matter being made up of particles.
- 4 An analogy is something that can be used to explain something else. One analogy of the structure of matter is students in school. **Explain** how this analogy models the structure of matter.

8.3 States of matter

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

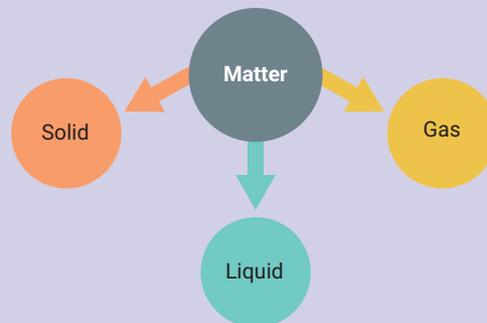
- ✓ describe the structure of solids, liquids and gases by applying the particle theory of matter.



Video activity
Solids, liquids and gases

GET THINKING

Prepare a concept map, similar to the one in Figure 8.3.1, to summarise the content in this module. Add to your concept map as you read the information. If you wish, you can include diagrams to help your understanding.



▲ FIGURE 8.3.1 A concept map for the states of matter. Add to it as you read through the module.

States of matter

Although all matter is made up of particles, there is a huge variety in the types of matter. One way of classifying matter is by the **state of matter** – whether it is a solid, a liquid or a gas. The states of matter are summarised in Table 8.3.1 (page 301).

state of matter

one of the forms in which matter can exist: solid, liquid, gas or plasma

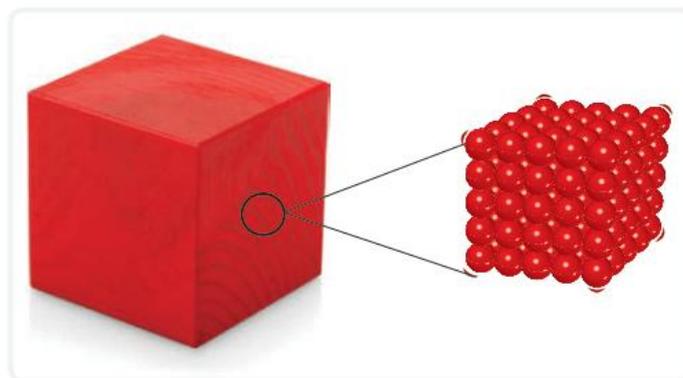


▲ FIGURE 8.3.2 Matter can exist as solids, liquids or gases.

You are already familiar with solids, liquids and gases. But what makes a solid a solid, a liquid a liquid, or a gas a gas? The particle theory of matter is useful in answering this question because it allows us to understand the structure of the different states of matter.

Solids

The particles in a **solid** are held close to one another in a fixed arrangement. This is because the strong **forces of attraction** between the particles pull them together. In a solid, the particles only have a small amount of energy, which allows the particles to vibrate where they are. However, they do not have enough energy to move away from one another.



▲ FIGURE 8.3.3 Solids are made of vibrating particles held close to one another.

solid

a state of matter in which the particles vibrate in fixed positions close to each other

force of attraction

a force that pulls objects together

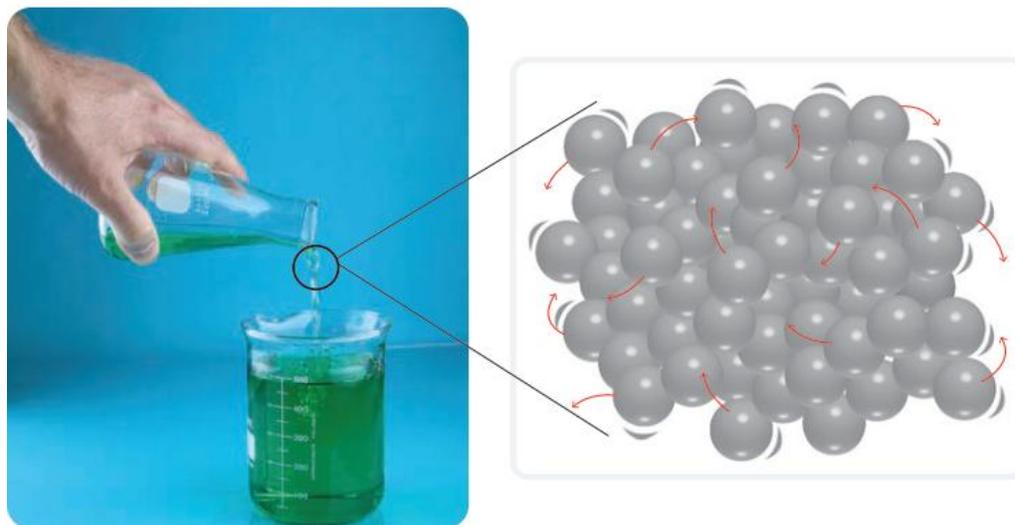
liquid

a state of matter in which the particles are close together but unable to break free of each other

Liquids

The particles in a **liquid** have more energy than those in a solid. The force of attraction between liquid particles is weaker than in solids. The energy of the particles allows them to move faster and overcome the force of attraction. Because of this, the particles in a liquid are not held in fixed places. Instead, they can move past one another as they break and then re-form forces of attraction with other particles.

Sheldon Perry/Shutterstock.com



▲ FIGURE 8.3.4 The particles in a liquid can move past one another.

Gases

Gases may be the hardest state of matter to understand because, in many instances, we cannot actually see them. This is because the particles in gases are as far apart as possible.

gas

a state of matter in which the particles are very far apart and move with a lot of energy

The particles in a gas have even more energy than those in liquids and they have the weakest force of attraction between them. This means that they are moving faster and can break free from one another. In fact, they keep moving until they collide with something else, either another particle or the wall of the container. They then bounce off the object and move in another direction. Therefore, the particles of a gas are spread throughout the container that the gas is held in.



▲ FIGURE 8.3.5 The particles in a gas are moving fast and are as far apart as possible.

☆ ACTIVITY

Modelling the states of matter

Choose a method from A–D to teach other students about the structure of solids, liquids and gases. You can use the following materials depending on your chosen resource:

- 3 or 4 ice cubes on a shallow dish such as a Petri dish
- water in a beaker
- water in a kettle
- white paper
- green paper
- magnifying glass
- tablet or phone to take photos and/or videos
- materials to make models.

As you complete the next modules, you may add more information to your resource.

A Using a green screen

- 1 Use a program such as PowerPoint or Keynote to create animations that model the structures of solids, liquids and gases.
- 2 Stick a green piece of paper over the lens of a magnifying glass.
- 3 Video the magnifying glass moving over the ice cube, water and then steam from the kettle.
- 4 Link your animations with your green screen videos so that the magnifying glass 'sees' the structure of the solid, liquid or gas.
- 5 Add a voice-over to describe the structure.

B Making a model

- 1 Create a model that represents the structures of solids, liquids and gases. For example, you could use marbles to represent the particles and find a way to make them move in the manner that the particles would.

C Making a YouTube video

- 1 Create a short YouTube video explaining the structure of solids, liquids and gases. What format will you use? For example, you could use cartoon characters, screen recording, real characters explaining or stop-motion videos.

D Role play

- 1 Use other students to act as particles in matter.
- 2 Be the director of the play to tell the actors how to move and behave when modelling a solid, a liquid or a gas.

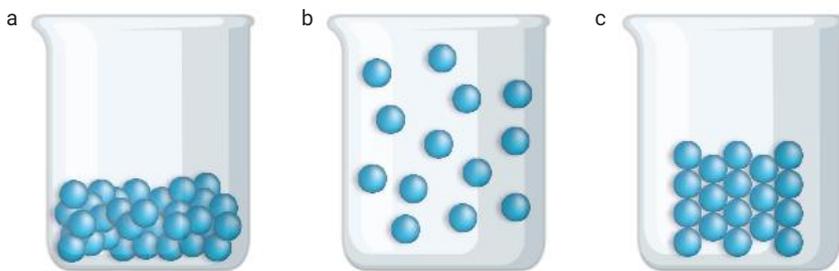
Summarising states of matter

▼ TABLE 8.3.1 Summarising the structure of solids, liquids and gases

Characteristic	State of matter		
	Solid	Liquid	Gas
Energy	Low	Medium	High
Forces of attraction	Strong	Medium strength	Very weak
Closeness to other particles	As close together as possible	Relatively close together	As far apart as possible
Arrangement of particles	Orderly arrangement in a fixed position	Irregular arrangement	Spread throughout the container
Movement of particles	Vibrating on the spot	Sliding past one another	Moving quickly in a straight line until they hit another particle or wall, then rebounding and continuing to move

8.3 LEARNING CHECK

- 1 **List** the three states of matter.
- 2 **Identify** each of the diagrams below as either solid, liquid or gas based on the arrangement of the particles.



- 3 **Construct** a Venn diagram to compare the structure of solids, liquids and gases.
- 4 Some solids, such as your desk, are very hard and rigid. Others, such as your jumper, are softer and more flexible. **Discuss** the possible reasons for these differences based on the particle theory of matter.

8.4 Properties of solids

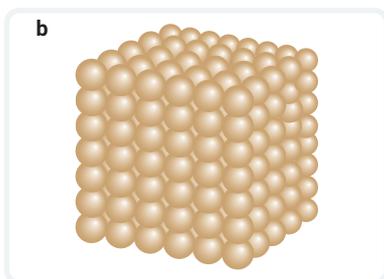
BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ list the main properties of solids
- ✓ explain the properties of solids.

GET THINKING

Make a list of five solids you can see around you. Identify at least one feature they have in common. Identify at least one way they are different. Why do you think this is?

3d_hokage/Shutterstock.com



▲ FIGURE 8.4.1 (a) A wooden cube has a fixed shape. (b) The shape of the cube is due to the arrangement of the particles.

Properties of solids

Although there are many different solids, they all have the same key properties.

- Solids have a fixed shape.
- Solids have a fixed volume.
- Solids do not flow.
- Solids cannot be compressed.

We can use the particle theory of matter, and hence the structure of solids, to explain these properties.

Solids have a fixed shape

If you put a piece of cake on your plate, it will remain in that shape (until you eat it!). In the same way, a book stays the same shape, as does a wooden picture frame. This is what we mean by having a fixed shape.

The reason that solids have a fixed shape is that their particles are held together by strong forces of attraction. This keeps the particles close together and prevents them from moving into different positions (Figure 8.4.1).

You might be thinking ‘But an ice cube will change shape when it melts’ or ‘A book changes shape when I turn a page’. You are correct. However, a solid doesn’t change its shape without a force acting on it.

Solids have a fixed volume

The **volume** of something is the amount of space that it occupies. A solid occupies a set amount of space because the strong forces of attraction between the particles hold them the same distance from one another.

One way to measure volume is to measure the sides and use this to calculate the volume. This works for regular shapes; however, many solids are not regular shapes. An alternative method is to put the solid into water in a measuring cylinder. The volume of the solid can be calculated from the increase in the volume when the solid is added (Figure 8.4.2).

volume

the amount of space occupied, measured in litres (L) or millilitres (mL)

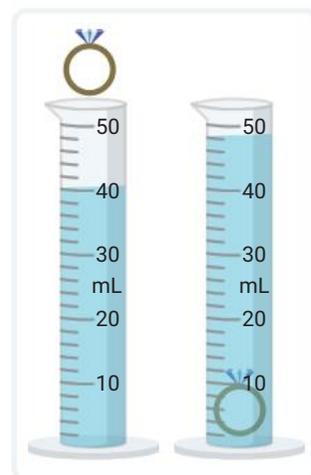
Solids do not flow

When something **flows**, it moves from one place to another in a steady stream. To do this, the particles must be able to move past one another into a new place. Solids are unable to flow because the forces of attraction mean that the particles are held together and can't move into a new place.

Solids cannot be compressed

If an object is **compressed**, it is squashed so that it takes up less space. The ability to do this is defined as **compressibility**. In a solid, the particles are already held closely together and cannot be easily pushed closer together. Therefore, solids can't easily be compressed.

You can try this yourself by trying to squash a book or a piece of wood. You may end up breaking it, but you can't squash it. Some objects, such as sponges and tennis balls, are deceptive and it may appear that you can compress them. In fact, these objects have air inside them too, and when you squash the object, you are compressing or squeezing out the air. The solid part of the object has not been compressed.



▲ **FIGURE 8.4.2** The volume of a solid object can be determined from the volume of water it displaces. The water level rose from 40 mL to 48 mL, so the ring has a volume of 8 mL.

flow
move from one place to another in a steady stream

compress
to squash something so it takes up less space

compressibility
the ability to be compressed (or squashed)



▲ **FIGURE 8.4.3** Luckily, solid bricks do not compress. Otherwise, our houses would get shorter as the bricks become squashed!

8.4 LEARNING CHECK

- 1 **List** the main properties of solids.
- 2 **Explain** why an ice cube is unable to flow.
- 3 **Apply** your understanding of the particle theory to explain why an apple has a fixed shape and volume (until it is eaten).
- 4 A metal cube is harder than a piece of wood. **Compare** the strength of the forces of attraction between the particles to suggest a reason for the difference in hardness.
- 5 The chair that you are sitting on is made of different solids. **Identify** and **explain** the properties of solids that make them suitable for use as a chair.
- 6 Some types of cheese are very soft and are easy to cut and spread. Would you classify soft cheeses as solids? **Justify** your answer.



Quiz
What are the properties of solids?

8.5 Properties of liquids

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ list the main properties of liquids
- ✓ explain the properties of liquids.



Interactive resource
Drag and drop:
Solids v liquids

Extra science investigation
Particle movement
in liquids

GET THINKING

Water is a liquid that you are very familiar with. You use it for washing, drinking and even swimming. What properties does water have that make it a liquid?

Properties of liquids

For a substance to be classified as a liquid, it must have the following properties.

- Liquids take the shape of the container.
- Liquids have a fixed volume.
- Liquids can flow.
- Liquids cannot be easily compressed.
- Liquids have an irregular arrangement of particles.

Just like with solids, the way the particles are arranged and behave in liquids determines these properties.

Liquids take the shape of the container

When a liquid is poured into a container, it spreads out to the edges of the container (Figure 8.5.1). This is because the particles can move over one another, filling the spaces until all the shape is filled.

Liquids have a fixed volume

The particles in a liquid are attracted to one another by forces of attraction. These forces keep the particles close to one another, so the volume of a liquid remains constant.

This property is easy to understand when we look at a sample of liquid in one container. However, it also applies when we move that same liquid into another container. For example, you use a measuring cup to measure 250 mL of milk when baking a cake. When you pour that milk into the mixing bowl, it will spread out in the larger container (Figure 8.5.2). Yet there is still only 250 mL of milk.



▲ **FIGURE 8.5.1** Liquids spread out to take the shape of the container.



iStock.com/RPMGsaas

▲ FIGURE 8.5.2 Even when the liquid is poured into a different container, it still has the same volume.



iStock.com/agrobacter

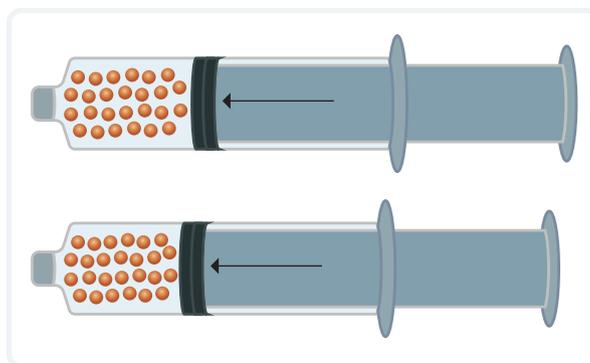
▲ FIGURE 8.5.3 Liquids can flow, allowing us to pour a glass of soft drink.

Liquids can flow

The energy of the particles in a liquid allows them to overcome the forces of attraction enough to move past one another. As they move, they can occupy a new space, taking the liquid from one place to another. This movement is called flowing (Figure 8.5.3).

Liquids cannot be easily compressed

Just like solids, liquids are made up of particles that are held closely together. There is very little space between them, which means that the particles can only be pushed a little bit closer together. Therefore, liquids can only be slightly compressed, or squashed, and this requires a large amount of force (Figure 8.5.4).



▲ FIGURE 8.5.4 Liquids cannot be easily compressed because the particles are already close together.

8.5 LEARNING CHECK

- 1 **List** the main properties of liquids.
- 2 **Explain** why liquids can flow.
- 3 Some people prefer to sleep on a waterbed, which is a mattress filled with water rather than a solid material. Use the properties of liquids to **explain** why waterbeds may be more comfortable than traditional mattresses.
- 4 **Draw** a labelled diagram to show what is happening at a particle level when water is poured into a glass.
- 5 **Compare** the properties of solids and liquids. Are there any common properties? Which properties are different?



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THIS SKILL:

- ▶ using scientific equipment to measure the melting and boiling points of water.

MELTING AND BOILING POINTS OF WATER

AIM

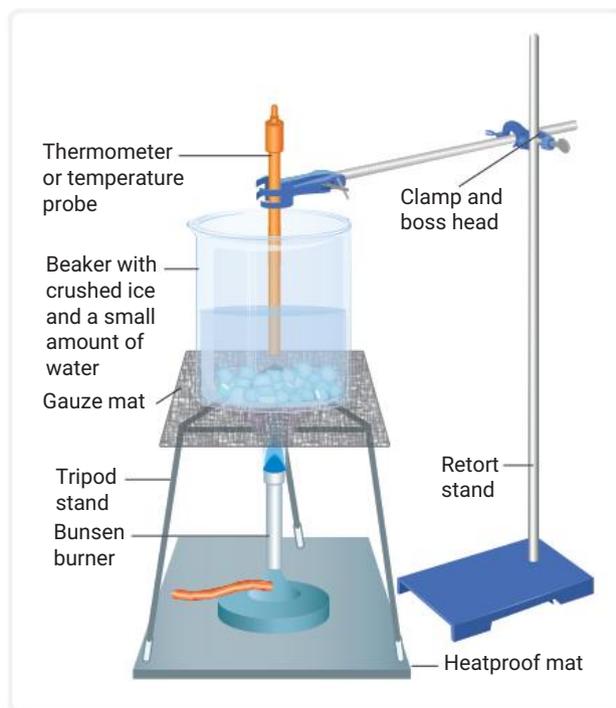
To determine the melting and boiling points of water

MATERIALS AND EQUIPMENT

- crushed ice
- 250 mL beaker
- tripod
- gauze mat
- heatproof mat
- Bunsen burner
- thermometer or temperature probe
- retort stand, boss head and clamp
- stirring rod

PROCEDURE

- 1 Set up the equipment as shown in Figure 8.6.1.
- 2 Draw a table to record the temperature at different times. Remember to put the independent variable (time) in the first column and the dependent variable (temperature) in the second column. Don't forget a title and units in the column headings.
- 3 Half-fill the beaker with crushed ice. Add enough water to just cover the ice. Stir well with the stirring rod.
- 4 Place the beaker on the gauze mat and heat the beaker using a blue flame on the Bunsen burner.
- 5 Record the temperature every minute if you are using a thermometer, or every 15 seconds if you are using a temperature probe.
- 6 Continue recording the temperature until the water has been boiling for five consecutive minutes.
- 7 Turn the Bunsen burner off and keep recording the temperature of the water every minute or 15 seconds for 10 minutes.



▲ FIGURE 8.6.1 How to set up your equipment

! Safety

Broken glass can cut skin. Clean up any broken glass immediately and put it in the glass bin.
Hot substances and objects can cause burns. Do not touch hot objects. Use equipment such as tongs to move hot equipment.
Wear safety glasses and lab coats at all times.

ANALYSIS

- 1** Explain, using the terms 'particles' and 'energy', why the ice melted.
- 2** Explain, using the terms 'particles' and 'energy', why the water boiled.
- 3** Draw a graph of the temperature at each time you measured it.
 - a** What type of graph should you use? How do you know what type of graph to use?
 - b** Give your graph a title: it may be the same as your table's title.
 - c** Label the axes, show units and use an even scale.
 - d** Draw a line of best fit.
- 4** What does the graph tell you?
 - a** What was the temperature when the ice was melting?
 - b** Describe what happened to the temperature of the water as the ice melted.
 - c** When did the temperature start to rise? What happened first?
 - d** What was the temperature when the water was boiling?
 - e** Describe what happened to the temperature as the water boiled.
- 5** Describe what is happening to the particles in the water in terms of energy and movement when the:
 - a** water is solid.
 - b** ice is melting.
 - c** water is all liquid and being heated.
 - d** water is boiling.
 - e** water is a gas.
- 6** What can you conclude from your experiment? Write a sentence to summarise what you learned about the melting and boiling points of water.

8.7 Properties of gases

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ list the main properties of gases
- ✓ explain the properties of gases.



Video activity
Properties of gases

Interactive resource
Simulation:
Introduction
to gases

GET THINKING

Long thin balloons filled with a gas such as air can be used to make different shapes, such as the animals in Figure 8.7.1. What properties do gases have that makes these creations possible? Discuss your ideas with a partner – how many properties can you list?



Africa Studio/Adobe Stock

▲ FIGURE 8.7.1 Balloon animals

Properties of gases

Remember that the particles of gases have more energy than particles in liquids or solids, meaning they are moving faster and are as far apart as possible. This is significantly different from the structure of liquids and solids, resulting in different properties.

Gases all have the same key properties.

- Gases take the shape of the container.
- Gases take the volume of the container.
- Gases can flow.
- Gases can be compressed.
- Gases can diffuse (spread out).

Gases take the shape and volume of the container

Gas particles continue to move until they collide with, and rebound from, the walls of the container. Therefore, gas particles will fill the container, taking its shape and volume. This may be hard to picture because we cannot see most gases. However, it is easy to understand with the example of a balloon, where the gas particles spread out and keep the balloon pushed out into its shape (Figure 8.7.2).



▲ FIGURE 8.7.2 The particles in a gas are spread out as far as possible, filling the container.

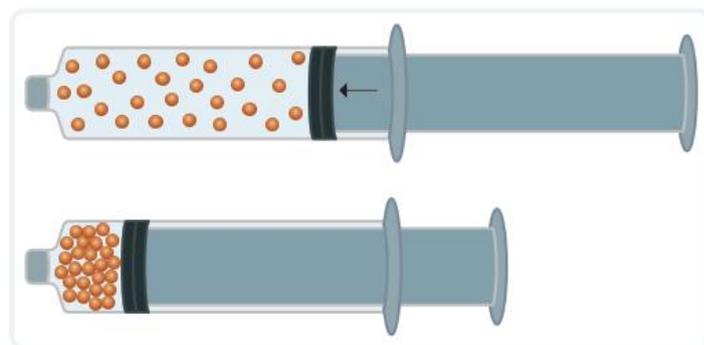
Gases can flow

When a substance flows, it moves from one place to another. Gases can flow because their particles can move into new spaces because of their motion and weak forces of attraction.

When a gas is in a container, such as LPG in a gas bottle, the gas particles are held in the container. When the container is opened, the particles continue moving out of the container. More and more gas particles move through the opening, allowing the gas to flow out of the container.

Gases can be compressed

Unlike solids and liquids, gases have a large amount of space between their particles due to the particles being spread as far apart as possible. This means that gas particles can be pushed closer together, compressing the gas (Figure 8.7.3).

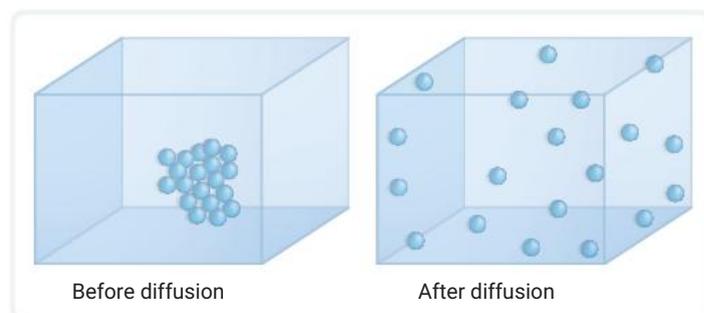


▲ FIGURE 8.7.3 When gases are compressed, the particles are pushed closer together.

Gases can diffuse

If someone is cooking dinner, you can often smell it as soon as you walk into the room, even though the food is still on the stove. This is due to **diffusion**. Diffusion is the movement of particles from an area of high concentration to an area of low concentration until they are evenly spread out.

Diffusion occurs in gases because the particles can move freely from one area to another. This means that gas particles, such as those producing the delicious smell of dinner, will spread out across the room (Figure 8.7.4).



▲ FIGURE 8.7.4 Diffusion of gases involves gas particles moving until they are evenly spread out.

8.7 LEARNING CHECK

- 1 **List** the main properties of gases.
- 2 **Describe** what happens to the gas particles over time if some gas is released in the corner of a container.
- 3 When the plunger of a sealed syringe, such as the one in the photo, is pushed in, the gas is compressed. **Explain** why it gets difficult to compress the gas when the volume becomes very small.
- 4 Natural gas does not have an odour. Gas companies that supply natural gas to households add the harmless chemical mercaptan. Mercaptan smells like rotten eggs to make it easy to detect gas leaks. **Explain** how mercaptan can achieve this function and possibly save lives.
- 5 **Draw** a labelled diagram to explain why a cricket ball cannot be squashed, but a tennis ball can.
- 6 **Create** a Venn diagram to compare the properties of solids, liquids and gases.



Alex Malarba/Dreamstime LLC

8.8 Changing state

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ name the changes in state
- ✓ explain why changes of state occur.



Video activity
Changing states of matter

Interactive resources
Simulation: Phase changes

Crossword:
Changing states

Extra science investigation
Changes of state and the weather

GET THINKING

Can you think of an example where a liquid becomes a solid or a gas? What causes it to change? What is happening to the particles during the change? As you learn about changes of state in this module, reflect on your answers. Were you correct? If not, what stopped you from correctly understanding the process?

Changing state

If you leave an ice cube in sunlight, it will become a liquid and eventually all of it will 'disappear' as it forms a gas. This is evidence that matter can change its state. However, for this to happen, energy needs to be either added or removed.



▲ FIGURE 8.8.1 An ice cube can change from a solid to a liquid and then to a gas.

Heating a substance

When a substance is heated (e.g. by putting it in the oven), the particles gain energy and move faster and further away from the other particles. This allows the particles to change their arrangement from the fixed arrangement in a solid, to moving over one another in a liquid, to moving quickly away from one another in a gas.

The process of a solid absorbing energy and becoming a liquid is called **melting**. Each substance requires a particular amount of energy to melt, and the temperature at which enough energy is provided is called the **melting point**. The process of changing into a liquid is called **liquefaction**.

melting

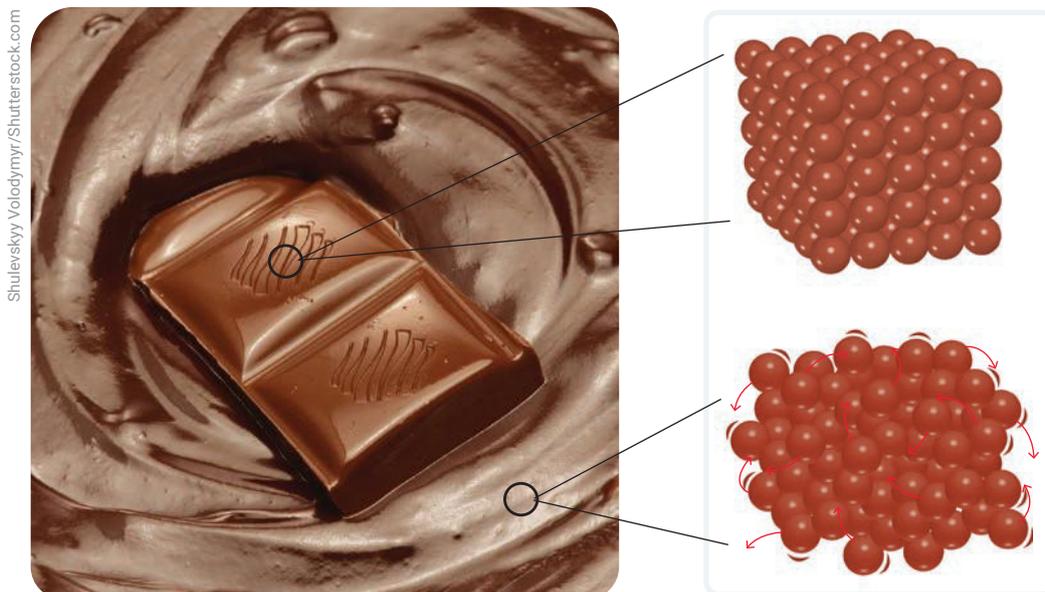
the process of changing from a solid to a liquid

melting point

the temperature at which a substance changes from a solid to a liquid

liquefaction

the process of changing into a liquid



▲ **FIGURE 8.8.2** Solid chocolate melts into liquid chocolate when heated. This gives the particles more energy to overcome the forces of attraction, move further apart and flow.

At any temperature, some of the particles at the surface of a liquid have enough energy to move away from the other particles and become a gas. This process is called **evaporation**.

If the liquid absorbs enough energy, it will reach the **boiling point**, the temperature when all of the liquid becomes a gas. At this temperature, the particles have enough energy to overcome the forces of attraction and move away from the other particles. This means that it has formed a gas. This process is called **boiling**.

Some substances, such as carbon dioxide, do not form liquids under normal conditions. Instead, their particles move from an orderly arrangement in the solid to being spread out in a gas. This process is called **sublimation**.

Boiling, evaporation and sublimation are all examples of **vaporisation** because they form vapours, or gases.

Table 8.8.1 lists the melting and boiling points of some common substances.

▼ **TABLE 8.8.1** The melting and boiling points of some common substances

Substance	Melting point (°C)	Boiling point (°C)
Dry ice (frozen carbon dioxide)	-57	-79 (sublimes)
Water	0	100
Table salt	804	1413
Gold	1064	2970
Diamond	3550	

evaporation

the process of changing from a liquid to a gas at a temperature lower than the boiling point

boiling point

the temperature at which all of a substance changes from a liquid to a gas

boiling

the process of changing from a liquid to a gas at the boiling point

sublimation

the process of changing from a solid directly to a gas

vaporisation

the process of forming a gas; evaporation, boiling or sublimation



▲ FIGURE 8.8.3 Icicles form when liquid water freezes, producing a solid.

Cooling a substance

As heat is removed from a substance (e.g. by putting it in the refrigerator), the particles lose energy. Therefore, they move slower and no longer have the energy to remain apart from one another. This means that a gas will become a liquid (**condensation**) or a liquid will become a solid (**solidification** or **freezing**). Substances that sublime when heated (change from a solid to a gas) will change from a gas directly back to a solid. This process is called **deposition**.

condensation

the process of changing from a gas to a liquid

solidification

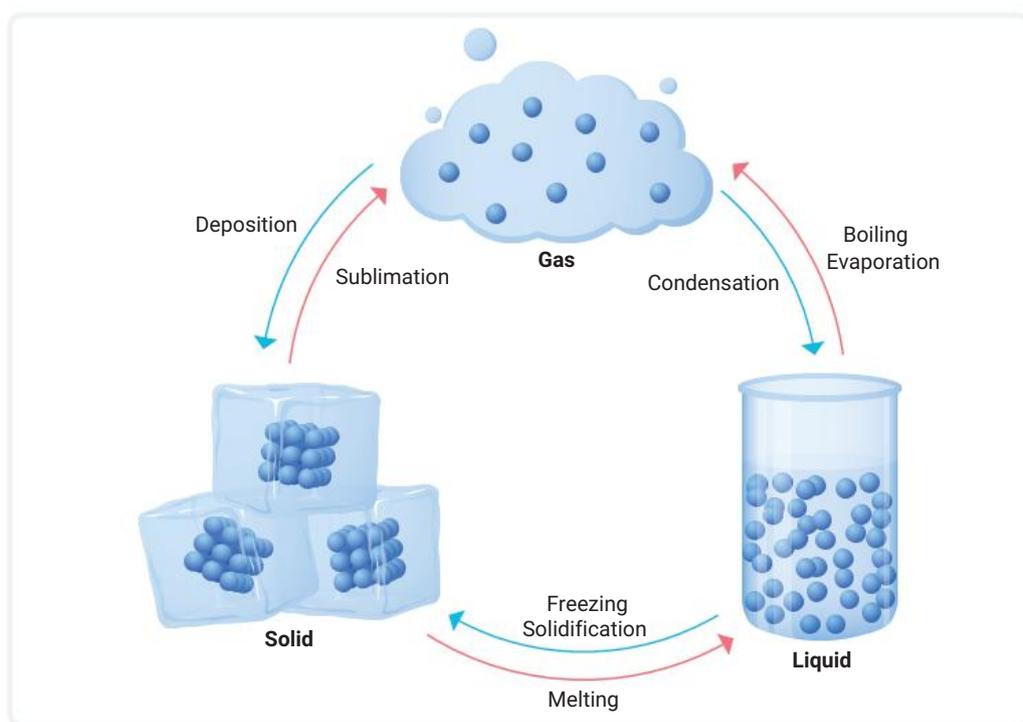
the process of changing from a liquid to a solid

freezing

the process of changing from a liquid to a solid

deposition

the process of changing from a gas to a solid



▲ FIGURE 8.8.4 A summary of the changes of state

Using changes of state

We can apply our understanding of changes of state, and how they occur, in many ways.

When we wash our clothes, they become wet with water, a liquid. For the clothes to become dry, the liquid water needs to change to a gas. One way to achieve this is by putting them on the clothesline in sunlight (Figure 8.8.5). The Sun's energy heats the particles, giving them enough energy to become a gas. Another method is to put the clothes in the dryer, which uses electricity to warm the clothes and evaporate the water.

Another example is the production of ice-cream. Ice-cream is a mixture of milk, cream, sugar and flavouring. These are mixed, making a liquid that can be solidified to become ice-cream. Any method of cooling the mixture enough will produce ice-cream. One method is to pour liquid nitrogen, which has a temperature of -196°C , over the liquid. The very

cold liquid nitrogen freezes the ice-cream, and then evaporates, leaving only the ice-cream behind (Figure 8.8.6). The very low temperature of the liquid nitrogen makes it dangerous, so it should only be used by adults wearing protective glasses, gloves and clothing.



▲ FIGURE 8.8.5 The Sun's energy can be used to change the liquid in wet fabric to a gas.



▲ FIGURE 8.8.6 The coldness of liquid nitrogen can be used to freeze ice-cream.

8.8 LEARNING CHECK

1 **Match** each term with its definition.

Melting	• The process of changing from a gas to a liquid
Condensation	• The process of changing from a gas to a solid
Liquefaction	• The process of changing into a liquid
Deposition	• The process of changing from a liquid to a solid
Evaporation	• The process of forming a solid
Freezing	• The process of forming a gas; evaporation, boiling or sublimation
Boiling	• The process of changing from a solid to a liquid
Sublimation	• The process of changing from a liquid to a gas at a temperature lower than the boiling point
Vaporisation	• The process of changing from a solid to a gas
Solidification	• The process of changing from a liquid to a gas at the boiling point

2 **List** the changes of state that require the removal of heat.

3 **Explain** why water vapour will condense on a car window on a cold morning.

4 When clothes dry on the clothesline, is the change of state evaporation or boiling? **Justify** your answer.

5 **Explain** what happens to the particles in water as its temperature increases and decreases.

6 **Draw** a flow chart to represent the changes of state.

7 Absolute zero (-273°C) is the lowest temperature that is possible. **Suggest** what happens to particles at this temperature and why it is not possible to get even lower temperatures.

8 The melting point of butane (a highly flammable gas) is -138°C , whereas the melting point of oxygen is -219°C . Provide a possible reason for the difference between these melting points.



Evaluating an investigation

SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ determining the melting point and boiling point of different substances
- ▶ evaluating an investigation by considering reliability and validity.

When you evaluate your procedure and results in an investigation, you should reflect on what you did, how well it was done and the results you obtained. Consider the following questions.

Are the results reliable?

An investigation is reliable if you get very similar results when repeated measurements are made.

- If you did the same investigation again, would you get the same results?
- Did you follow the same procedure exactly every time?
- How many times did you test the same substance? Repeating the test multiple times on the same substance increases the reliability of the data.

Are the results valid?

An investigation is valid if it measures what it is supposed to measure.

- Were the variables controlled properly?
- Was the same equipment always used?
- Were there any sources of error?

Can you make any suggestions for improvement?

- How could you improve the procedure or better control the variables?
- Were there variables that you thought you had controlled but didn't? What were they?
- Could you measure the melting or boiling point differently? Describe any alternative method of measurement.

Can you suggest any further investigations?

- Are there new questions that you could explore in another investigation? These could be questions to extend the investigation or new predictions you want to test.



Video

Science skills in a minute: Accurate and valid results

Science skills resource

Science skills in practice: Evaluating an investigation

MELTING POINTS OF MATTER

AIM

To determine the melting point of six materials, and the boiling point of water

MATERIALS AND EQUIPMENT

- | | |
|--|--|
| <input checked="" type="checkbox"/> wax block | <input checked="" type="checkbox"/> marshmallow |
| <input checked="" type="checkbox"/> gallium block | <input checked="" type="checkbox"/> 6 beakers |
| <input checked="" type="checkbox"/> crayon | <input checked="" type="checkbox"/> hot plate |
| <input checked="" type="checkbox"/> ice cube | <input checked="" type="checkbox"/> infrared thermometer |
| <input checked="" type="checkbox"/> piece of chocolate | |

Safety

Take care when using the hot plate.
Use thermally insulated gloves or tongs when handling hot objects.

PROCEDURE

- 1 Make a prediction about the temperature at which each material will melt (the melting point). Record this in the results table.
- 2 Place the wax block, gallium block, crayon, ice cube, piece of chocolate and marshmallow into six separate beakers.
- 3 Place the beakers onto the hot plate, but do not turn the hot plate on.
- 4 Wait 3–4 minutes to see if any of the materials begin to melt at room temperature. Record your observations in the 'Measured melting point' column in the results table.
- 5 Turn on the hot plate and move the dial to the lowest setting.
- 6 Begin measuring the temperature of the glass beakers using the infrared thermometer. Measure the temperature at frequent intervals (e.g. 20 seconds).
- 7 Carefully observe whether the materials in the beakers are beginning to melt. As soon as you see part of the material has melted, record the temperature in the results table.
- 8 Continue to monitor the temperature and materials while slowly adjusting the setting of the hot plate to make it warmer.
- 9 Once all six materials have completely melted, remove the beakers containing the wax, crayon, chocolate and marshmallow. Leave the melted ice on the hot plate.
- 10 Increase the temperature of your hot plate further until the water reaches boiling point. Record the temperature at which this occurs.

ANALYSIS

- 1 List the materials in order of lowest melting point to highest melting point. Was this what you expected?
- 2 Did any of the materials melt at room temperature?
- 3 What was the state of the materials at the beginning of the experiment? What was their state at the end of the experiment?
- 4 Why did a change in state occur?
- 5 How do your results compare to those of the group next to you? Did your materials melt at the same temperature?

CONCLUSION

Compare the melting points of all six materials, discussing whether any were similar.

RESULTS

Copy and complete the results table.

Material	Predicted melting point (°C)	Measured melting point (°C)	Boiling point (°C)
Wax			
Crayon			
Chocolate			
Marshmallow			
Ice cube			

8.10 Properties of water

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe and calculate the density of substances
- ✓ explain why substances are buoyant in water
- ✓ explain how surface tension works.



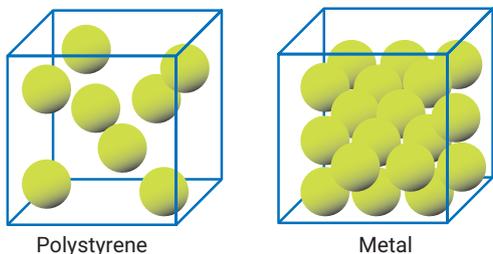
Interactive resource
Simulation: Density

GET THINKING

Some substances float on water, some substances sink in water. Make a list of four substances that float on water, and four substances that sink. Why do you think some things float and some sink?



▲ FIGURE 8.10.1 Identical sized cubes of brass (top row), tin, copper (middle row), iron, zinc and aluminium (bottom row) have different masses because of their density.



▲ FIGURE 8.10.2 A substance with a higher density, like the metal represented on the right, has a greater mass in the same space than a lower-density substance, like the polystyrene on the left.

density

the mass per unit volume of an object

Density

Density is a physical property of solids, liquids and gases. Consider the identically sized metal cubes in Figure 8.10.1. If you were to pick up two of the cubes and compare how heavy they are, they would be different. The lead cube would be much heavier than the aluminium cube, even though they are the same size. This is because lead has a higher density than aluminium.

The **density** of a substance is its mass per unit volume. The more mass per volume, the higher the density. Figure 8.10.2 shows two identically sized cubes of different substances. The substance on the left is a low-density material, such as polystyrene. The substance on the right is a high-density substance, such as a metal. The polystyrene has less mass in the same volume than the metal, so it has a lower density.

Calculating the density of objects

If you know the mass and volume of a substance, you can determine its density by using the following equation.

$$\rho = \frac{m}{V}$$

ρ = density, measured in grams per litre (g/L) or grams per millilitre (g/mL)

m = mass, measured in grams

V = volume, measured in litres or millilitres

For example, if a substance has a mass of 66 grams and a volume of 2 litres,

then it has a density of $\rho = \frac{66}{2} = 33 \text{ g/L}$.

If a substance has a mass of 8 grams and a volume of 2 millilitres, then it has a density of $\rho = \frac{8}{2} = 4 \text{ g/mL}$.

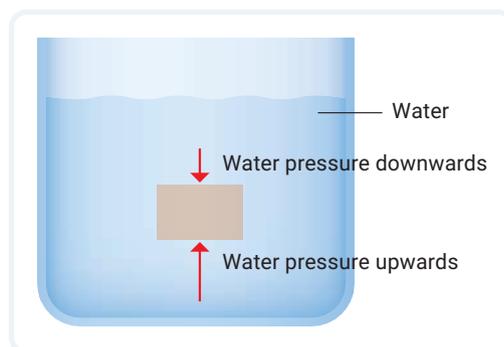
Buoyancy

Buoyancy is the ability of a liquid to apply an upwards force to an object in the liquid. When you swim, you often feel lighter due to the upwards force. If an object is placed in water, it experiences pressure from all directions. The pressure gets stronger as it gets deeper into the water. As a result, if you ignore the effects of weight, there is more pressure pushing up on an object than pushing down. This creates an overall upwards force called the **buoyant force**. Figure 8.10.3 shows an object in water. Stronger pressure from below is represented by the longer arrow, less pressure from above is shown by the shorter arrow.

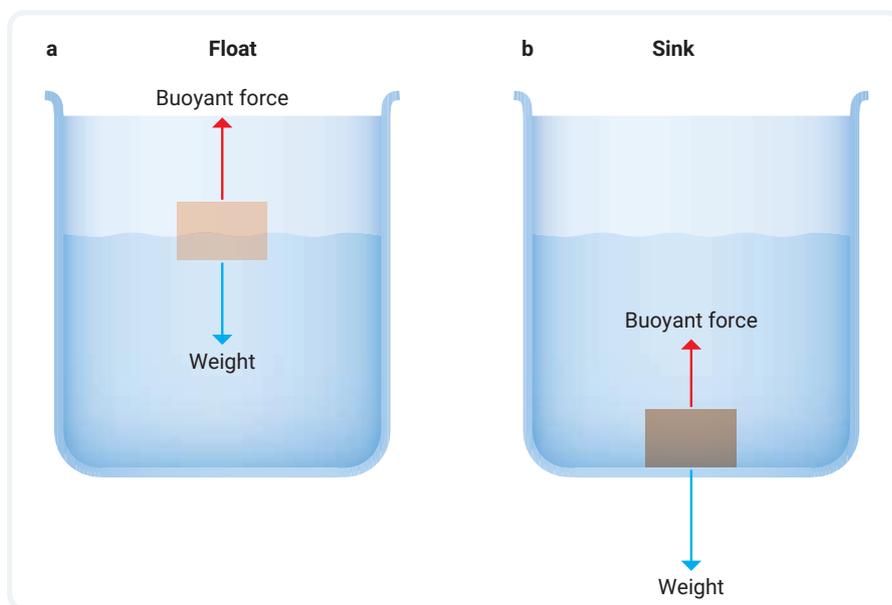
All objects exert a downwards force due to gravity. We call this the weight of an object. You learned about weight in Chapter 5. The weight, or force, of an object compared to the buoyant force determines if an object will sink or float, as seen in Figure 8.10.4. If the buoyant force is greater or equal to the weight, then the object will float (Figure 8.10.4a). If the weight is greater than the buoyant force, then the object will sink (Figure 8.10.4b).

buoyancy
the ability of a liquid to apply an upwards force to an object

buoyant force
the upwards force acting on objects in a liquid



▲ FIGURE 8.10.3 When you consider the pressure forces of water alone (i.e. when weight is ignored), the pressure on an object in water is stronger pushing upwards than pushing downwards.



▲ FIGURE 8.10.4 (a) If the buoyant force is the same or greater than the weight of the object, then the object will float. (b) If it is less than the weight, the object will sink.

surface tension
tension at the surface of a substance caused by attractive forces between particles

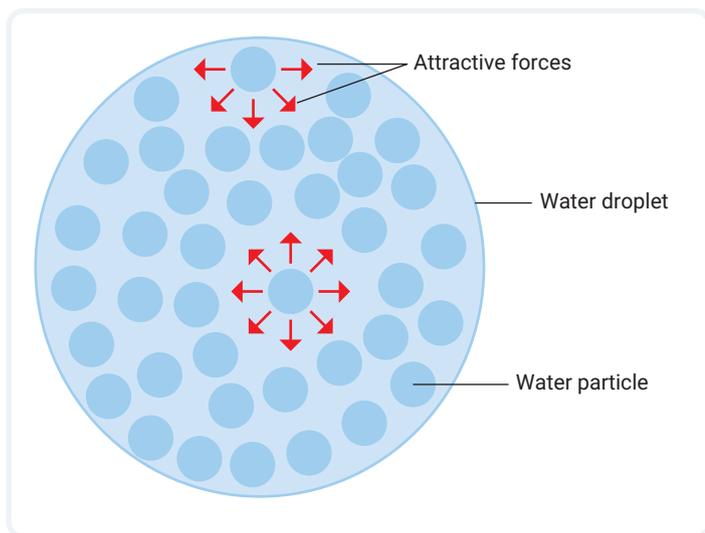
Surface tension

When it rains and water settles on leaves, you often see an effect called water beading. You might also see this on a car if it has rained overnight. You might expect the water to spread out over the surface of the leaf. However, a property of water called **surface tension** results in roughly spherical water droplets forming. You see the same effect when water drips very slowly from a tap. The water builds up, then forms a droplet as it falls.



▲ FIGURE 8.10.5 Water beading on a leaf is due to surface tension.

Particles of water are held together by forces of attraction. Figure 8.10.6 shows a water droplet containing many particles of water. The particles in the middle of the droplet experience attractive forces equally in all directions, shown by the red arrows. The particles on the surface only have some of the attractive forces as they are not completely surrounded by other water particles. The overall force on the surface particles is not balanced and this causes the particles to be pulled inwards. This pulls the water into a spherical shape if it is not in a container. This explains the shape of water droplets and water beading on surfaces.



▲ FIGURE 8.10.6 Surface tension is caused by unbalanced forces acting on water particles at the surface.



Dorling Kindersley Ltd/Alamy Stock Photo

▲ FIGURE 8.10.7 An object may float on the surface of water due to surface tension, but sink if it is pushed below the surface.

Another effect of surface tension is that it creates a stronger layer at the top of a water body like a lake, or water inside a container. The particles at the surface are more strongly attracted to other water particles. Due to this, some small objects can float on the surface when they would otherwise sink. If you place a paperclip into a beaker of water and force it under the surface, it will sink, because its weight is greater than the buoyancy force. But if you carefully place a paperclip flat on the water's surface, the surface tension will allow it to float.

8.10 LEARNING CHECK

- 1 **Describe** how you can observe two examples of surface tension.
- 2 **Calculate** the density of the following substances:
 - a an object with a mass of 146 g that has a volume of 0.34 L.
 - b an object with a mass of 5.3 g that has a volume of 9.4 mL.
- 3 **Draw** diagrams showing weight and buoyant forces to **explain** why some objects will sink and some objects will float.
- 4 **Explain** how the density of an object might affect its buoyancy.
- 5 An object placed in water has a weight force that is greater than the buoyant force. **Explain** how it might still be able to float.



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ using an electronic scale to take measurements
- ▶ measuring the density of an object and comparing it to accepted values.

In this module, you will determine the density of some common metals. You will use an electronic scale to weigh the metals and measure their mass.

Electronic scales are commonplace in science laboratories. Scientists use scales to quickly and accurately measure the mass of objects.



▲ **FIGURE 8.11.1** An electronic scale and a weigh dish

To use an electronic scale:

- 1 Ensure the surface of the scale is clean of any debris and/or fingerprints. If needed, gently wipe the surface of the scale clean and dry.
- 2 Place the scale on a flat and stable surface. The precision of the scale depends on factors such as the stability of the surface it rests on.
- 3 Turn on the scale and wait for the balance screen to display a reading.
- 4 If you are using a weigh dish to weigh the substance, place the empty weigh dish on the scale and press 'zero' or 'tare' to automatically deduct the mass of the empty dish from the scale.
- 5 Carefully add the substance to be weighed to the weigh dish. This can be done with the weigh dish on the scale or removed. If you remove the dish, be careful not to set it in any liquids or grease that will add weight to it. If you leave the dish on the scale, be careful not to spill any substance on the scale.
- 6 Place the weigh dish back on the scale and record the mass indicated by the digital display.

MEASURING THE DENSITY OF DIFFERENT SUBSTANCES

AIM

To measure the density of water and common metals

MATERIALS AND EQUIPMENT

- large measuring cylinder
- electronic scale
- water
- small pieces of common metals

PROCEDURE

PART 1: MEASURING THE DENSITY OF WATER

- Using a measuring cylinder, measure exactly 10.0 mL of water.
- Place a weigh dish on the electronic scale and zero the scale.
- Carefully add the 10.0 mL of water to the weigh dish and record the mass of the water.

PART 2: MEASURING THE DENSITY OF METALS

- Weigh a piece of metal using the electronic scale. Record the mass of the metal.
- Half fill a large measuring cylinder with water.
- Record the volume reading as accurately as possible. Remember to read the meniscus as explained in Module 3.8.
- Add a small piece of metal to the measuring cylinder and ensure the metal is fully submerged.
- Record the final volume reading as accurately as possible.
- Subtract the initial volume from the final volume to calculate the volume of the metal and record this.
- Repeat steps 1–6 for a number of different metals.

RESULTS

Record all results in a table like the one below.

ANALYSIS

- Use the information in Module 8.10 to calculate the density of water and record it in the results table.
- Use the *Science 7–10 Data Book* (NSW Education Standards Authority) or research the accepted value for the density of water. Were you close? If not, what might have caused the difference?
- Use the information in Module 8.10 to calculate the density of the metals.
- Use the data book or research the accepted value for the density of the metals you used. Were you close? If not, what might have caused the difference?
- Explain why different metals have different densities.
- Why do metals not float in water?

CONCLUSION

Write a conclusion for each part of the investigation. Remember to state how close your results were to the accepted values.

Metal	Mass metal (g)	Initial volume water (mL)	Final volume water (mL)	Volume of metal (final volume – initial volume) (mL)	Density of metal (mass/volume) (g/mL)

DATA SCIENCE



Learn more about using secondary data in investigations in **Module 2.5**.

8.12 The water cycle

BY THE END OF
THIS MODULE, YOU
WILL BE ABLE TO:

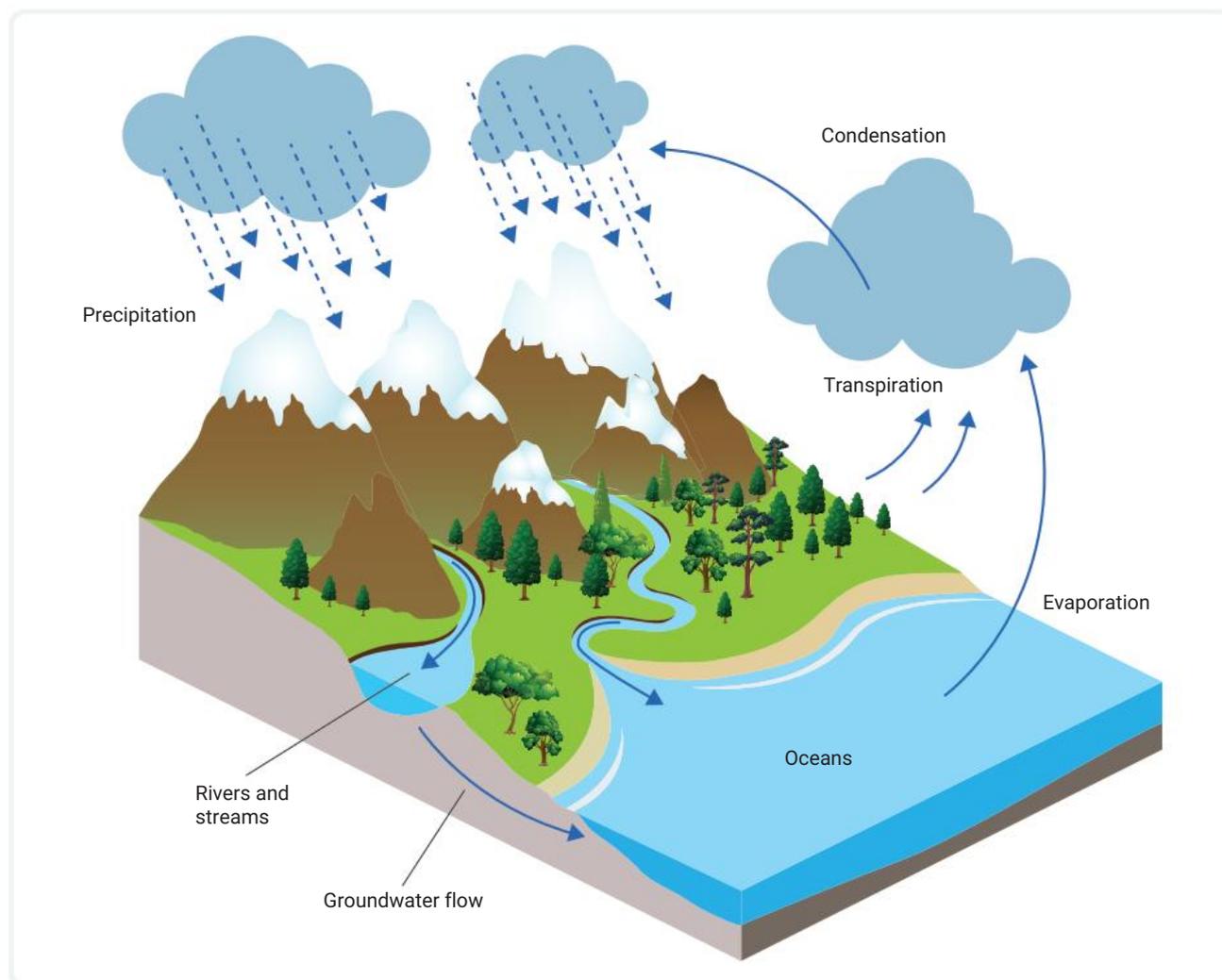
- ✓ identify where water is found on Earth as solid, liquid and gas
- ✓ describe the movement of water in the water cycle.

How does water move around the environment?

Water moves around the land, oceans, lakes, rivers, groundwater and the atmosphere constantly in a series of processes known as the water cycle. Figure 8.12.1 shows a model of the water cycle. Different processes occur to move the water around in solid, liquid and gas forms.



Video activity
The water cycle



▲ FIGURE 8.12.1 The water cycle shows the movement of water in its different forms

DATA
SCIENCE



Learn more about
scientific models in
Module 2.9.

The processes that move water around are:

- Evaporation – water from oceans and other water bodies changes state from liquid to gas and rises into the atmosphere.
- Transpiration – water from the land is taken up into trees, where it evaporates mostly through the leaves and rises into the atmosphere.
- Condensation – the gaseous water from evaporation and transpiration changes back into liquid and sometimes solid water in the form of clouds.
- Precipitation – water falls as a solid, snow or hail, or as liquid rain back to the ground. This water often makes its way back to the ocean by rivers, streams and from water running over the land.
- Infiltration – water on the ground passes through the surface and into the soil below. Some of this water flows underground, some of it is taken up by plants.

8.12 LEARNING CHECK

- 1 Identify** places in the water cycle where water is a:
 - a** solid.
 - b** liquid.
 - c** gas.
- 2 Explain** in which processes in the water cycle water goes through the same change of state. For example, in which processes does water change from a liquid to a gas? List the processes for each change of state.
- 3** Using the processes of the water cycle, **explain** how snow on top of a mountain could eventually end up in the ocean.
- 4 Create** a circular flow chart to track the movement of water around your local environment.

8 REVIEW

REMEMBERING

- 1 Describe the arrangement of particles in a:
 - a solid.
 - b liquid.
 - c gas.
- 2 Copy and **complete** the following table by placing a tick for each property that solids, liquids and gases exhibit.

Property	Solids	Liquids	Gases
Have a fixed shape			
Have a fixed volume			
Can be compressed			
Take up space			
Have mass			
Able to flow			

- 3 What term describes the following situations?
 - a A solid turns into a liquid.
 - b A gas turns into a liquid.
 - c A liquid turns into a solid.
 - d A gas turns into a solid.
- 4 What state of matter (solid, liquid or gas) is formed in the following situations?
 - a A gas condenses.
 - b A liquid evaporates.
 - c A solid sublimates.
- 5 **Identify** the following sentences as true or false. If they are false, rewrite them to make them true.
 - a Liquids keep the same volume, but solids don't.
 - b Gases take up the same amount of space as liquids.

- c Liquids and solids cannot be compressed, but gases can.
- d Solids maintain their shape, whereas liquids and gases only maintain their volume.
- e The density of a substance depends on its mass and volume.
- f There is much more space between the particles in a gas than there is between the particles in a solid.
- g Gases are always made of much smaller particles than solids are.

UNDERSTANDING

- 6 Substance X is in a container. When the container is tipped, substance X flows. What else would you need to know to determine what state substance X is in?
- 7 **Identify** whether the following state changes require the addition or removal of energy.
 - a Boiling
 - b Condensing
 - c Freezing
 - d Evaporating
- 8 **Explain** the difference between evaporation and boiling.
- 9 **Explain** the difference between buoyancy and surface tension.
- 10 For each of the following pairs of options, which option would have particles with the most energy? **Justify** your answer.
 - a Solid butter or melted butter
 - b Honey or the smell of honey
- 11 **Explain** how the particles in ice move compared with the particles in water and steam.

APPLYING

- 12 Apply** the properties of each substance to identify them as solids, liquids or gases.
- a** A rock
 - b** Fog
 - c** Honey
 - d** Fur
 - e** An iceberg
 - f** The smell of a flower
 - g** Butter
- 13 Explain** why you can walk through a sheet of water (such as a waterfall) but not through a sheet of glass.
- 14 Explain** why bread that is baking smells so much better than cold bread.
- 15** When water boils, there are bubbles in it. What do you think is in the bubbles? **Explain** your answer.
- 16** A cork floats on water but a pebble will sink. **Explain** how the forces acting on the cork and the pebble, when placed into a container of water, are different.
- 17** In each of the following situations, which process requires the addition of the most heat?
- a** Melting ice or melting the same amount of gold if they are starting from the same temperature
 - b** Boiling vegetable oil or boiling water
 - c** Subliming carbon dioxide or subliming iodine (Hint: What other information do you need to be able to answer this?)
- 18** 'Gases exert much more pressure than solids.' **Decide** whether this statement is true or false and **explain** your answer.
- 19 Explain** why cordial diffuses in water quickly, but if it is added to solid ice, it doesn't mix.

EVALUATING

- 20** Why does the bathroom mirror fog up after you have a hot shower without the fan on?
- 21 Suggest** why dogs pant when they are hot.
- 22** As you go up into the atmosphere, such as up a mountain or in an aeroplane, the air gets thinner and the pressure decreases. This is why your ears 'pop' – they need to equalise the pressure inside and outside.
- a Compare** the arrangement of particles in the air at the top of a mountain and at the bottom of the mountain.
 - b Explain** why you are not allowed to take a pressurised container of gas on an aeroplane.
- 23** Why is it easier to float in a swimming pool while holding your breath than when you let it out?

CREATING

- 24 Create** a concept map of all the key terms in this unit. Make as many links as possible between them.
- 25 Create** a presentation that follows the movement of a particle of water through the water cycle. Include the correct names of the processes involved as well as whether the water is in a solid, liquid or gaseous state. Your presentation could take the form of a poster, flow chart, cartoon or digital animation.

SCIENCE IN DEPTH STUDY

#8

1 Connect what you've learned

Do some research into Antarctic sea ice. Describe the changes in the state of water from summer to winter and back to summer again. Where else might the water be moving through the environment in the Antarctic?

2 Check your thinking

The amount of sea ice present in Antarctica in winter is decreasing each year. The ice is thinner and there is less of it. Where does all the missing ice go?

3 Get into action

As land ice melts and ocean temperatures increase, the sea levels across the world are rising. This is having negative effects on low-lying land such as the Pacific Islands. Do some research into the negative effects of rising sea levels.

4 Communicate

Create a poster for years 7 and 8 students that explains some of the effects of decreasing levels of sea ice in Antarctica and how it affects other parts of the world.



Margaret Block West/Shutterstock.com

9

Mixtures

9.1 Classifying matter (p. 326)

Matter can be classified as a pure substance or a mixture, based on the type of particles.

9.2 Pure substances (p. 330)

Pure substances can be elements or compounds.

9.3 Solubility (p. 332)

The solubility of a substance describes how much can dissolve in a certain volume.

9.4 WORKING SCIENTIFICALLY: Identifying variables to test (p. 334)

Measuring solubility of different substances

9.5 Types of mixtures: solutions (p. 336)

A solution is produced when a solute dissolves in a solvent.

9.6 WORKING SCIENTIFICALLY: Controlled variables (p. 340)

How does temperature affect solubility?

9.7 Types of mixtures: suspensions (p. 342)

A suspension is produced when an insoluble solute is too heavy to remain dispersed throughout the solvent.

9.8 Types of mixtures: colloids (p. 344)

Colloids are produced when the particles of an insoluble solute is light enough to remain dispersed throughout the solvent.

9.9 WORKING SCIENTIFICALLY: Observing to make classifications (p. 346)

Observing mixtures

9.10 SCIENCE IN CONTEXT: Air quality (p. 348)

Air is a mixture that is monitored for the number of pollutants it contains.



Mirek Kijewski/Shutterstock.com

You probably know that we need to breathe in air to give our bodies oxygen. But what about fish – do they breathe? Fish also need oxygen, but they need to get it from the water!

- ▶ Why is it important that oxygen dissolves in water?
- ▶ What factors must be monitored to ensure that there is enough oxygen in the water for fish in an aquarium?
- ▶ How would life on Earth be different if oxygen couldn't dissolve in water?

▲ FIGURE 9.0.1 Fish need to obtain oxygen from water.

#9 DIVE INTO SCIENCE!

At the end of this chapter, you can complete the Science in Depth Study #9. You can use the information you learn in this chapter to complete the project.

Assessments

- Prior knowledge quiz
- Chapter review questions
- End-of-chapter test
- Depth study: Secondary sources investigation

Videos

- Science skills in a minute: Identifying variables (9.4); Controlling variables (9.6)
- Video activities: Elements and compounds (9.2); Solutions (9.5); Measuring air quality (9.10)

Science skills resources

- Science skills in practice: How to identify variables (9.4); Controlling variables for a valid investigation (9.6)
- Extra science investigations: Design your own solubility investigation (9.3); How much sugar? (9.5)

Interactive resources

- Simulations: Build a compound (9.2); Concentration of solutions (9.5)
- Drag and drop: Classifying mixtures and pure substances (9.1); Solubility (9.3)
- Crossword: Solutions, suspensions and colloids (9.8)
- Label: Compound, element or mixture? (9.2)

9.1 Classifying matter

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define matter, pure substance and mixture
- ✓ use diagrams to model pure substances and mixtures
- ✓ give examples of pure substances and mixtures
- ✓ classify a substance as a pure substance or a mixture
- ✓ compare pure substances and mixtures.

GET THINKING

A glass of seawater looks the same as a glass of tap water – it is clear and colourless. Yet, after swimming in the ocean, it often feels as though there is something scratching your skin. Discuss these observations with a partner – what inferences can you make?



▲ FIGURE 9.1.1 After swimming in the ocean, it can feel as though something is scratching your skin.

What are pure substances and mixtures?

In Chapter 8, you learned that matter is anything that has mass and occupies space. In fact, everything around you is made up of matter. This includes the air, water, your body, a road, a pen, the food you eat and even the screen of your phone. While it is useful to have a name for all these things, matter is such a broad group that it doesn't tell you much about their properties. Therefore, scientists have different ways of classifying matter based on common properties. One method of classifying matter is according to whether it is a **pure substance** or a **mixture**.

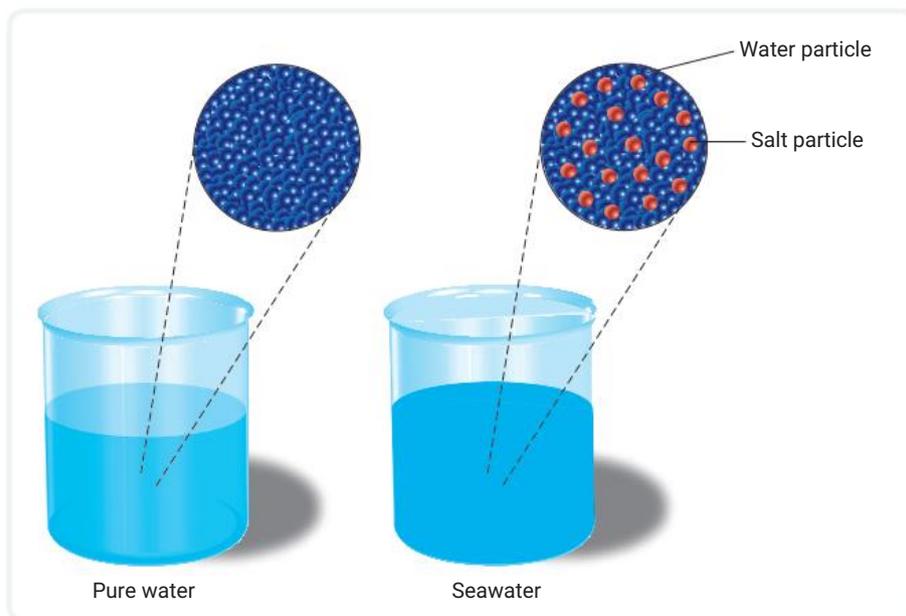
pure substance

a substance made up of the same type of particle

mixture

a substance made up of different types of particles that are physically combined

We classify matter as a pure substance or a mixture based on the type of particles that it is made up of. In a pure substance, all the particles are the same. For example, in a glass of pure water, there are only water particles present. However, mixtures are made up of different types of particles. Seawater is a mixture because it is made up of water particles as well as salt particles.



▲ **FIGURE 9.1.2** In pure water all the particles are the same, making it a pure substance. Seawater is made up of different particles and so is a mixture.

It is often helpful to use simple models to represent concepts. To model pure substances and mixtures, we can represent the particles with different shapes or colours. In Figure 9.1.2, water particles are shown in blue and salt particles are shown in red. In pure water, a pure substance, all the particles are blue. In contrast, in the mixture, seawater, there are blue and red particles.

Classifying matter as pure substances or mixtures

Sometimes it is easy to identify matter as a mixture because you can see that it is made up of different things. For example, the batter of chocolate chip biscuits (Figure 9.1.3) is obviously a mixture because you can see the batter and chocolate chips. Other mixtures that are easy to classify are soda water, dirt, freshly squeezed orange juice and a meat pie.



Interactive resource
Drag and drop:
Classifying mixtures
and pure substances



Brent Hofacker/Shutterstock.com

▲ **FIGURE 9.1.3** Chocolate chip biscuit batter is an example of a mixture.



Valentyn Volkov/Shutterstock.com

▲ **FIGURE 9.1.4** A cup of tea is a mixture because it is made up of water and tea.

How was it made?

Some mixtures are not easily classified just by looking at them because you cannot see different parts to them. Therefore, we need more information to help classify them as a pure substance or a mixture. One way to help classify a sample of matter is to think about how it was made. For example, a cup of tea looks the same throughout (Figure 9.1.4). Yet you know that it is a mixture because you know that it contains water as well as tea and perhaps even sugar and milk.

Can it be separated?

Another method of evaluating whether matter is a mixture is to think about whether it can be separated into components. You cannot separate pure substances by simple methods, but you can separate mixtures. For example, if you heated pure water until it boiled, it is still water, but now it is a gas rather than a liquid. However, if you boiled seawater, the water would become a gas and the salt would be left behind. This means that it has been separated into the parts that made up the mixture. You will learn more about the methods that are used to separate a mixture in Chapter 10.

Table 9.1.1 lists some pure substances and mixtures.

▼ TABLE 9.1.1 Examples of pure substances and mixtures

Pure substance	Mixture
Distilled water	Tap water
Sugar	Air
Salt	Sand
Copper	Self-raising flour
Oxygen	Brass

☆ ACTIVITY 1

Research activity: Alloys

An alloy is a mixture in which the main component is a metal. The properties of the alloy are different from the properties of the pure metal, making it useful for different purposes. For example, pure gold is very soft. However, an alloy of gold is harder, making it suitable for jewellery.

What to do

- 1 Conduct research about the alloys of bronze, brass, 18-carat gold, sterling silver, stainless steel and cast iron. For each one, find out what:
 - a pure substances are in the mixture.
 - b properties are different in the alloy compared with the pure metal.
 - c the alloy is used for.
- 2 Summarise the information in a table.



▲ FIGURE 9.1.5 This statue is made from bronze, which is an alloy.

Teaching to learn about pure substances and mixtures

☆ ACTIVITY 2

9.1

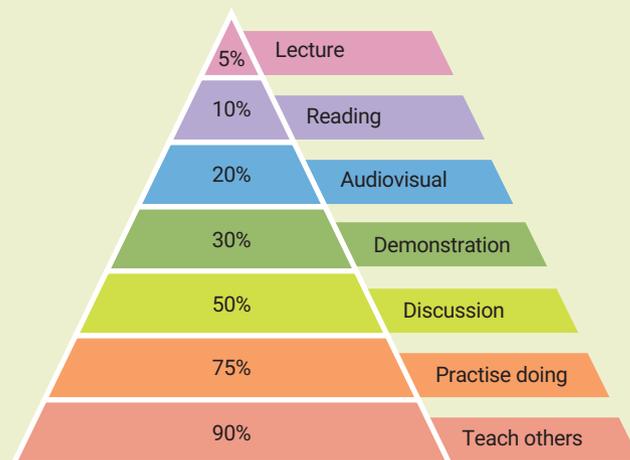
A lot of research has been done to understand the best method to learn, and remember, new information. Figure 9.1.6 summarises the effectiveness of different learning methods. It shows that teaching others is the most effective learning method because students can remember nearly 90 per cent of what they learn by teaching others. However, they can only remember 5 per cent of what they learn by listening to a lecture.

Materials and equipment

- distilled water
- solid copper sulfate
- 250 mL beaker
- stirring rod
- spatula

Procedure

- 1 Pour approximately 100 mL of distilled water into the beaker.
- 2 Take a photo of the water and make a list of its properties.
- 3 Take a photo of the solid copper sulfate and make a list of its properties.
- 4 Use the spatula to add a small amount of copper sulfate to the water. Use the stirring rod to mix the two substances together.
- 5 Take a photo of the mixture and make a list of its properties.
- 6 Use your photos to create a slide show to teach others the difference between a pure substance (the distilled water and the copper sulfate) and a mixture (the copper sulfate in the water).
- 7 Show your presentation to your family to find out how clearly and accurately you explained the ideas.



▲ FIGURE 9.1.6 The effectiveness of different study methods: teaching others is more effective than listening a lecture.

9.1 LEARNING CHECK

- 1 Describe one simple method that can be used to separate the components of a mixture.
- 2 **State** two examples of a:
 - a pure substance.
 - a mixture.
- 3 **Explain** why it may be difficult to classify something as a pure substance or a mixture.
- 4 During a science class, Amelia poured 100 mL of lemonade into a beaker. She then heated the beaker over a Bunsen burner for 15 minutes. A sugary syrup was left behind. Based on Amelia's observation, is lemonade a pure substance or a mixture? **Justify** your answer.
- 5 Draw a diagram to **model** a:
 - a mixture made of equal amounts of three different substances.
 - pure substance.
 - a mixture made of a small amount of one substance in a large amount of a second substance.
- 6 Your teacher will provide you with a small sample of seawater. Leave this in a small shallow dish for a few days until the water has evaporated. Take a photo of the seawater at the start and the end. Refer to the photos to **justify** why seawater is classified as a mixture.

9.2 Pure substances

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe and compare elements and compounds
- ✓ give examples of elements and compounds
- ✓ classify a pure substance as an element or a compound.

atom

the smallest part of an element that gives the element its chemical properties

element

a pure substance made up of only one type of atom; it cannot be broken down into a simpler substance

compound

a pure substance whose particles are made up of two or more different atoms chemically bonded together

GET THINKING

Have you heard water being described as H_2O ? What do you think ' H_2O ' means? Does this mean that water isn't a pure substance? Discuss these questions with a partner in a 30-second brainstorm. As you work through the module, think back to your discussion. Were you correct?

Particles in pure substances

You now know that a pure substance is made up of only one type of particle. But did you know that these particles can be made up of smaller structures called **atoms**? In your later studies of science, you will learn a lot more about atoms. In this chapter, we are only going to consider whether the atoms are the same or not.

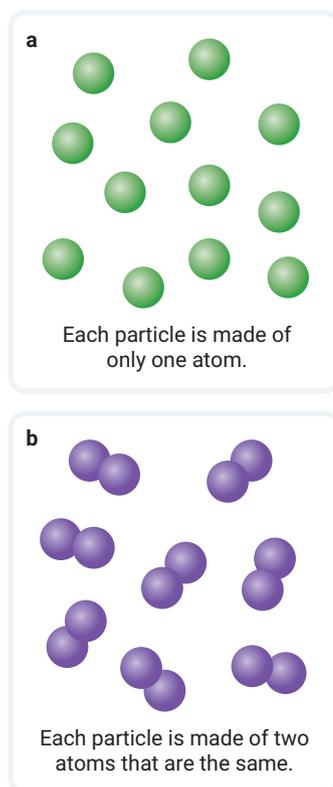
Elements

An **element** is a pure substance whose particles are made up of only one type of atom (Figure 9.2.1). Oxygen, hydrogen, nitrogen and neon are all examples of elements.

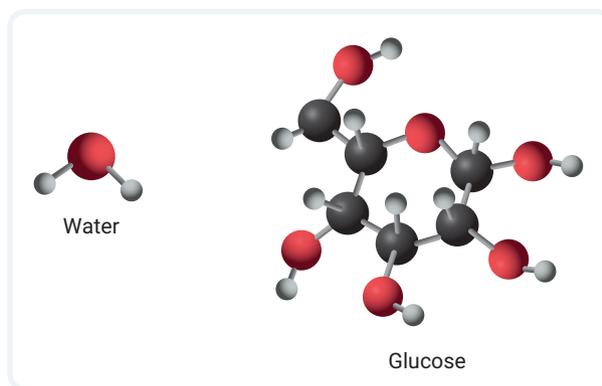
Compounds

A **compound** is a pure substance whose particles are made of different types of atoms held together by chemical bonds (Figure 9.2.2). Some compounds have particles that only have two different atoms joined together while other compounds have particles made of many different atoms.

Water is an example of a compound. Each particle in water is made up of three atoms – two atoms of hydrogen (H) and one atom of oxygen (O). This is why water is referred to as H_2O .



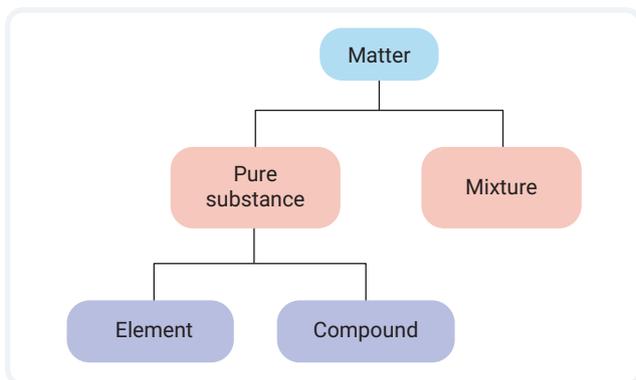
▲ **FIGURE 9.2.1** The particles of elements can consist of (a) one atom, such as neon, or (b) more than one atom, such as oxygen.



▲ **FIGURE 9.2.2** Models of particles of the compounds water (H_2O) and glucose ($C_6H_{12}O_6$). You can see that compounds have more than one type of atom in each particle.

Putting it together

In summary, all matter can be classified as a pure substance or a mixture (Figure 9.2.3). Pure substances can be further classified into elements or compounds.



◀ FIGURE 9.2.3 A tree diagram showing the classification of matter



Video activity
Elements and compounds

Interactive resources
Simulation: Build a compound

Label: Compound, element or mixture?

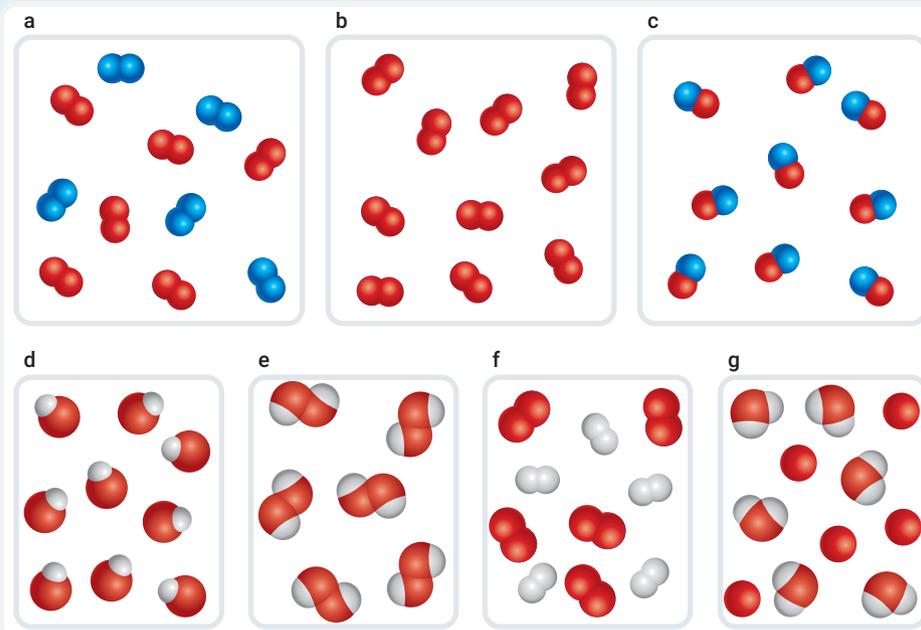
You will learn about classifying mixtures in Modules 9.5, 9.7 and 9.8.

9.2 LEARNING CHECK

1 Define:

- a element.
- b compound.

2 Classify each of the following as an element, a compound or a mixture.



3 State one similarity and one difference between:

- a elements and compounds.
- b mixtures and compounds.

9.3 Solubility

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define soluble, insoluble and solubility
- ✓ give examples of soluble substances and insoluble substances
- ✓ classify substances as soluble or insoluble.

GET THINKING

Speed challenge! How many things can you list in 30 seconds that:

- can dissolve?
- cannot dissolve?

Compare your list with that of the person sitting next to you. Did they have some that you hadn't considered?

dissolve

when a substance is mixed with another and the particles from both substances spread out evenly until they are too small to see

soluble

able to dissolve in another substance

insoluble

unable to dissolve in another substance

When you put a teaspoon of sugar in water, it seems to disappear – it has **dissolved** in the water. However, when you put a teaspoon of Milo in cold milk, only some of it dissolves (Figure 9.3.1).

When something dissolves, it looks as though it has disappeared. In fact, it is still there, but it is so spread out that we can't see it anymore. If something can dissolve, it is described as **soluble**. If it cannot dissolve, it is described as **insoluble**. Whether something is soluble or not depends on factors such as what the substance is, what it is being added to and the temperature (Figure 9.3.2).

Describing something as soluble or insoluble is a qualitative description. We can also describe it quantitatively by stating the amount that can dissolve in a certain volume. This is known as the **solubility** of a substance. For example, at 25°C, the solubility of table salt is 360 g/L, meaning that 360 grams of table salt can dissolve in 1 litre of water. In comparison, the solubility of sugar is 2000 g/L. Therefore, 2000 grams (2 kg) of sugar can dissolve in 1 litre of water.



▲ **FIGURE 9.3.1** Only some of the Milo dissolves in milk.

solubility

how much of a substance can dissolve in a certain volume of another substance

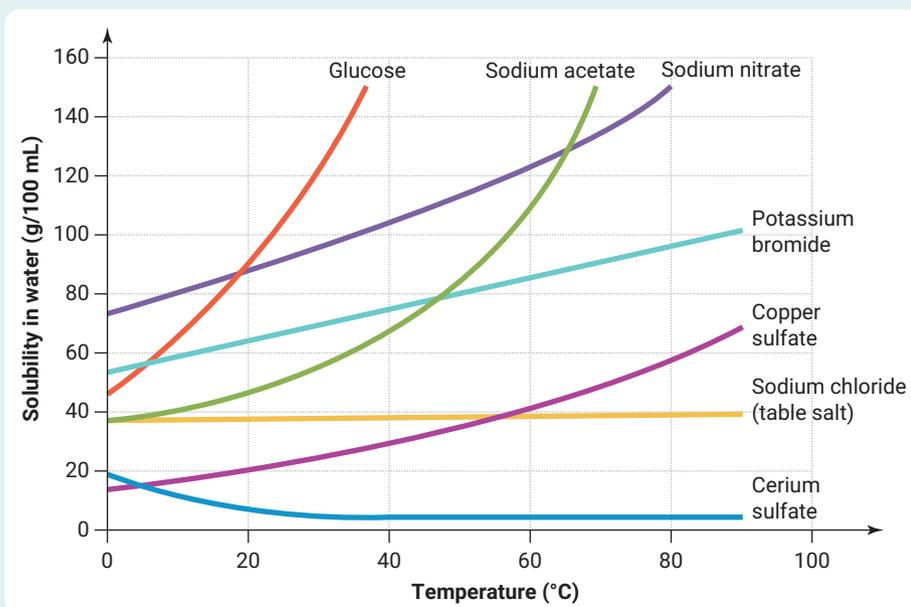


◀ **FIGURE 9.3.2** (a) When a solid is soluble in water (e.g. table salt) it will dissolve, and we cannot see the solid any more. (b) When a solid is insoluble (e.g. calcium carbonate), it will not dissolve in water and so we can still see the solid.



9.3 LEARNING CHECK

- Define:**
 - soluble.
 - insoluble.
- Create** a table with the column headings 'Soluble' and 'Insoluble'. In your table, **list** three things in your house that are soluble and three things that are insoluble.
- Classify** each of the following as soluble or insoluble.
 - Iron nail
 - Washing detergent
 - Instant coffee
 - Wool
 - Carbon dioxide (you may need to conduct some research for this one)
- When we design products, it is important that we choose appropriate materials to make them. Why is it important that solubility is considered when making products?
- The graph below shows the solubility of different substances at different temperatures. **Use** this information to answer the following questions.



- Describe** what happens to the solubility of glucose as the temperature increases.
- Name** a substance that becomes less soluble as the temperature increases.
- Your friend is making play dough and asks you to heat some water so that more salt will dissolve. Will heating the water allow more table salt to dissolve? **Explain** your answer.
- What mass of sodium acetate can dissolve in 100 mL of water if the temperature is 60°C?



Interactive resource
Drag and drop:
Solubility

Extra science investigation
Design your own
solubility investigation

DATA SCIENCE



Learn more about quantitative and qualitative data in **Modules 2.2 and 2.3.**



Identifying variables to test

SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ using science equipment to gather data about the solubility of substances
- ▶ identifying variables to test in an experiment.

The aim of an experiment helps you to identify the correct variables you need to test in the experiment. If you do not test the correct variables, you may not be able to answer the testable question that you are investigating.

Consider a simple experiment with the aim 'To determine the volume of liquid different containers can hold'. To investigate this, you need to identify the independent and dependent variables. You must do this before you plan and conduct the experiment. Then you can achieve the aim of the experiment.

- The independent variable, or the variable you change deliberately, is the different types of containers. You might choose a beaker, an ice-cream container and a water bottle as your types of containers.
- The dependent variable, or the variable that you measure, is the volume of water. You need to decide how you are going to measure this variable. For example, if you are measuring a volume of a liquid, will you use a measuring cylinder?



Video
Science skills
in a minute:
Identifying
variables

**Science skills
resource**
Science skills
in practice:
How to identify
variables

MEASURING THE SOLUBILITY OF DIFFERENT SUBSTANCES

AIM

To measure the solubility of salt and sugar

MATERIALS AND EQUIPMENT

- 3 × 250 mL beakers
- 100 mL water
- electronic scale
- stirring rod
- spatula
- 50 g salt
- 250 g sugar

Safety

Broken glass can cut skin. Clean up any broken glass immediately and put it in the glass bin.

PROCEDURE

- 1 Place a clean dry beaker onto the electronic balance, recording the mass of the beaker. Do not 'zero' the balance.
- 2 Add exactly 50 g of salt to the beaker. Record the final mass.
- 3 Repeat steps 1 and 2 with 250 g of sugar.
- 4 Measure 100 mL water and place it into a clean dry beaker.
- 5 Add a small amount of the salt to the water and stir until completely dissolved.
- 6 Repeat this process, adding salt until the salt no longer dissolves.
- 7 Record the mass of the beaker with the remaining salt and calculate how much salt was added to the water.
- 8 Repeat steps 4–7 with the sugar. Measure another 100 mL of water in a new beaker and then add the sugar.

RESULTS

- Record your results in a table like the one below.

Solid	Initial mass of beaker and solid (g)	Final mass of beaker and solid (g)	Mass of solid added (g)
Salt			
Sugar			

- Calculate the solubility of the salt and sugar in water, using the information on p. 332.
- Create a graph to compare the solubilities of the salt and sugar. Consider the most appropriate type of graph to use to present this data.

ANALYSIS

- What was the independent variable in this investigation? What was the dependent variable?
- Write a paragraph describing the changes to the solution as you added more salt or sugar. You should include information on the mass you measured and any observations you made in your writing.
- Propose a reason why the two substances have different solubilities.
- Justify the type of graph you chose to present your data.
- How you could extend this investigation? For example, what other substances could you test?
- Challenge: Research the known values for the solubility of salt and sugar (sucrose). Determine how close you were in your experiment and propose reasons for any differences.

9.5 Types of mixtures: solutions

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define solute, solvent, solution, saturated, unsaturated, supersaturated, concentrated solution and dilute solution
- ✓ describe the structure and properties of solutions
- ✓ classify solutions as saturated, unsaturated or supersaturated
- ✓ classify solutions as concentrated or dilute.



Video activity
Solutions

Interactive resource
Simulation:
Concentration
of solutions

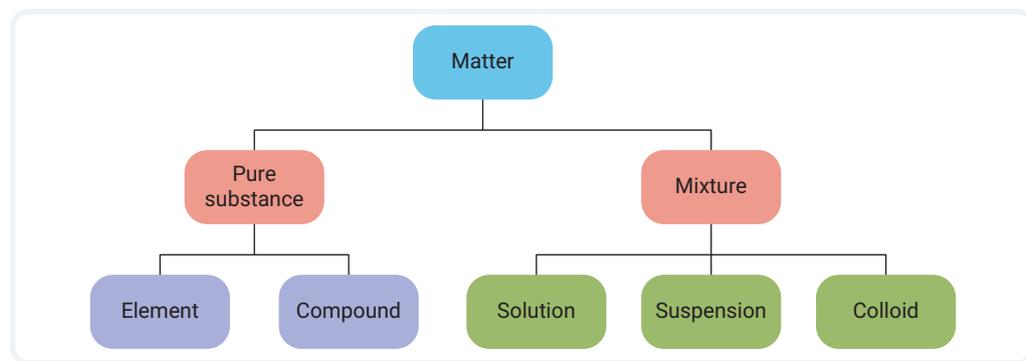
Extra science
investigation
How much sugar?

GET THINKING

This module contains a lot of new terms! Create flashcards for the key terms. Choose how you will make your flashcards; for example, on paper or by using an app. Test yourself with your flashcards until you remember the terms and their definitions. This will make it easier to understand the concepts as you learn them in class.

Classifying mixtures

In Module 9.1, you learned how all matter can be classified as either a pure substance or a mixture. And in Module 9.2, you learned about classifying pure substances as elements or compounds. In this module and modules 9.7 and 9.8, you will learn about the different types of mixtures – solutions, suspensions and colloids.



▲ FIGURE 9.5.1 A tree diagram for the classification of matter, including types of mixtures

The structure of a solution

You already know that when a sugar cube is added to a cup of tea and stirred, the small white solid sugar grains seem to vanish as they dissolve in the water. When a substance dissolves, its particles break apart and spread out evenly in the other substance. You can no longer see the original substance because it has separated into particles that are too small to see.

The substance that dissolves, such as sugar, is called the **solute**. The substance that does the dissolving, such as water, is called the **solvent**. The particle theory says that the solvent and solute particles have attractive forces between them when they dissolve. If these forces do not form, then a substance will not dissolve. Together, the solute and the solvent form a type of mixture known as a **solution**.

In a sugar–water solution, the sugar is the solute because it is the substance that dissolves. The water is the solvent because it does the dissolving. The sweetened water that is produced is the solution. Similarly, a cup of coffee (the solution) is produced when instant coffee (the solute) dissolves in the water (the solvent) (Figure 9.5.2).

solute

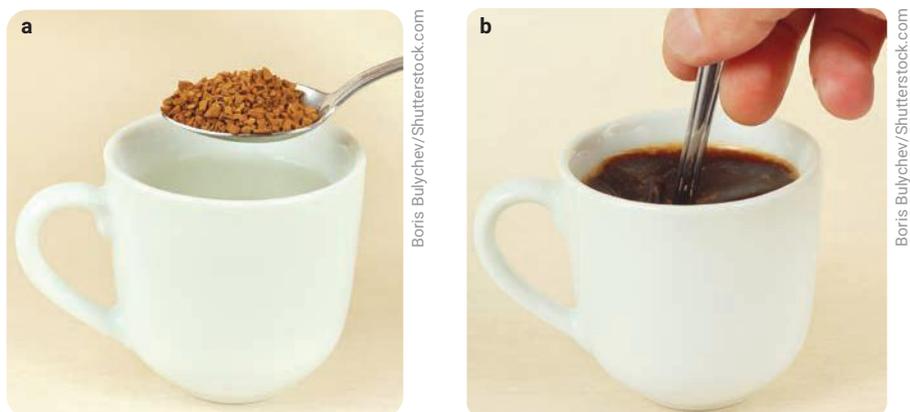
a substance that dissolves in another substance to form a solution

solvent

a substance that dissolves another substance to form a solution

solution

a mixture formed when a solute dissolves in a solvent



▲ FIGURE 9.5.2 (a) The solute (solid coffee) and solvent (water); (b) the solution (coffee drink)

Water is a common solvent. It is often called the universal solvent because so many substances dissolve in it. However, not everything dissolves in water. For example, nail polish does not dissolve in water, but it does dissolve in another solvent called acetone. Other liquid solvents include ethanol, kerosene and turpentine.

You are already familiar with many solutions. A salt solution is formed when salt (a solid solute) dissolves in water (a liquid solvent). Vinegar is a solution made by dissolving acetic acid (a liquid solute) in water (a liquid solvent). Soda water is made when carbon dioxide (a gas solute) is dissolved in water. We know there is a gas dissolved in soda water because, when we open the bottle, we see bubbles and hear some of the gas escape.

Appearance of solutions

Solutions are usually **transparent**, but this does not mean they cannot be coloured. If blue food colouring is added to water, you can still see through the solution. It can be described as blue (its colour) and transparent (because we can see through it) (Figure 9.5.3).



▲ FIGURE 9.5.3 Solutions are usually transparent and may be coloured.

Concentration

Solutions can be described as **concentrated** or **dilute**. This refers to the amount of solute that is in the solution. A concentrated solution has a large amount of solute in a certain volume of the solution. By contrast, a dilute solution has only a small amount of solute in the same volume of the solution (Figure 9.5.4).

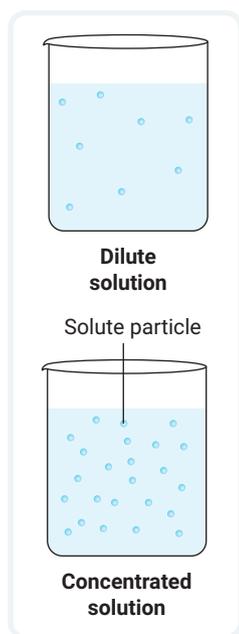
The terms ‘concentrated’ and ‘dilute’ are referred to as qualitative data. This is because they are a comparison or description only, not a measured amount. If we measure the amount of solute in the solution, we can calculate the **concentration**. This is often measured in the number of grams of the solute in a litre of solution. Because concentration is a measured amount, it is classified as quantitative data.

transparent
see-through

concentrated
having a large amount of solute in a certain volume of solution

dilute
having a small amount of solute in a certain volume of solution

concentration
the amount of solute present in a specified amount of solution



▲ **FIGURE 9.5.4**
A dilute solution contains fewer solute particles than in the same volume of a concentrated solution.

saturated solution

a solution that has the maximum amount of solute dissolved in the solvent

unsaturated solution

a solution that can dissolve more solute

supersaturated solution

a solution that contains more solute than is normally able to dissolve in it at a certain temperature

In a coloured solution, the intensity of colour changes with concentration. The solute gives the solution its colour. Therefore, if there is more solute in a solution, then it will be a darker colour, like the two cups of tea in Figure 9.5.5.



▲ **FIGURE 9.5.5** (a) A dilute cup of tea will be lighter in colour than (b) a more concentrated cup of tea.

Saturation

Another physical property of solutions is saturation. This is a qualitative description that refers to how much solute is dissolved in a solvent compared with the solubility (how much can dissolve).

- A **saturated solution** has the maximum amount of solute dissolved in the solvent. If more solute is added to a saturated solution, it cannot dissolve and therefore will remain as a solid.
- An **unsaturated solution** can have more solute dissolve in it. Therefore, if more solute is added to an unsaturated solution, it will dissolve.
- **Supersaturated solutions** are a special case. In most cases, if a solution is heated, more solute can dissolve than at the lower temperature. If this solution is slowly cooled, all of the solute may remain dissolved. The solution produced is described as supersaturated because it contains more solute than is normally soluble. If more solute is added to a supersaturated solution, it will disturb the solution and the extra dissolved solute can no longer stay dissolved. This means that the solute that was added, plus the extra solute that was dissolved, will appear as a solid.

☆ ACTIVITY

What substances are soluble?

Aim

To determine if various substances are soluble or insoluble

Materials and equipment

- 5 × 100 mL water
- 5 × 250 mL beaker
- spatula
- stirring rod
- white sugar
- table salt
- vinegar
- vegetable oil
- marble

Procedure

- 1 Measure out approximately 100 mL water into each of the five beakers.
- 2 Use the spatula to add one spoon of each substance into each beaker, as outlined in Table 9.5.1.

▼ TABLE 9.5.1

Beaker	Volume water	Substance to be added:
Beaker 1	100 mL	1 spoon white sugar
Beaker 2	100 mL	1 spoon table salt
Beaker 3	100 mL	1 spoon vinegar
Beaker 4	100 mL	1 spoon vegetable oil
Beaker 5	100 mL	1 marble

- 3 Stir each of the beakers, making a note of whether the added substance dissolves or not.

Analysis

- 1 Which of the substances dissolved? Which did not?
- 2 Are there any similarities between the substances that dissolved?
- 3 Some of the substances tested were solid, others liquid. Did you observe any pattern in whether solids or liquids dissolve in water?

Conclusion

Write a conclusion outlining your findings. Which substances were soluble? Which were not? Was it easy to decide whether a substance was soluble or insoluble?

9.5 LEARNING CHECK

- 1 **Match** each term with its definition.

Concentrated solution	• A solution with a small amount of solute in the solution
Unsaturated solution	• A solution with the maximum amount of solute dissolved in the solution
Dilute solution	• The substance that does the dissolving
Solute	• A solution containing more than the maximum amount of solute in the solution
Saturated solution	• A solution with a large amount of solute in the solution
Supersaturated solution	• What is produced when a solute dissolves in a solvent
Solvent	• A solution that can still dissolve more solute
Solution	• The substance that is dissolved

- 2 **Describe** what happens to the particles of a solute when they dissolve in a solvent.
- 3 **Reflect** on the way a solution is made and what solutions look like. **List** four solutions in your home. For each one, **state** the solute and solvent and **describe** its appearance.
- 4 **Explain** why a saturated solution has a greater concentration than an unsaturated solution of the same solute.
- 5 When you get wet from the rain, you may describe yourself as saturated. **Compare** the use of the term 'saturated' in this example to its use in describing solutions.
- 6 **Discuss** whether 'weak' and 'strong' are the correct scientific terms to describe drinks of cordial that have different amounts of flavouring.
- 7 Challenge: A solution contains 5 g of sodium carbonate dissolved in 2 L of water. **Calculate** the concentration of the solution in grams per litre.



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ using science equipment to gather data about solubility and temperature
- ▶ identify and control variables in an experiment.

In an experiment where you have an independent and a dependent variable, you need to make sure that only the independent variable is causing the change in the experiment. To do this, you must control all other variables. In a valid experiment, all variables other than the independent variable are controlled.

For example, if you are testing which type of cleaner removes a stain best, the independent variable you are testing is the type of cleaner. So, to control your other variables, you need to have the same type of stain and use the same amount of cleaner. This will make your experiment a fair test, which lets you compare the types of cleaner. If you changed the amount of cleaner *and* the type of cleaner, then you would never be sure if it was the type or the amount that caused the change.



Video

Science skills in a minute: Controlling variables

Science skills resource

Science skills in practice: Controlling variables for a valid investigation

HOW DOES TEMPERATURE AFFECT SOLUBILITY?

AIM

To determine whether changing the temperature of water affects the solubility of sugar

MATERIALS AND EQUIPMENT

- 3 × 250 mL beakers
- 100 mL of water
- ice bath
- hot plate
- thermometer or data logger
- small bag of sugar
- stirring rod
- spatula
- electronic scale

! Safety

Take care when using the hot plate.

Do not handle hot objects.

Broken glass can cut skin. Clean up any broken glass immediately and put it in the glass bin.

PROCEDURE

- 1 Measure 100 mL water into each of the three beakers.
- 2 Measure the temperature of one of the beakers of water. Record this temperature.
- 3 Place the beaker on the electronic scale and 'zero' the scale. Leave the beaker on the scale until the next steps are completed.
- 4 Add one spatula of sugar and stir until dissolved. Repeat until no more sugar dissolves.

- 5 Record the final mass of the beaker and sugar.
- 6 Cool one of the beakers of water in the ice bath until it is 10°C.
- 7 Repeat steps 3–5 for the 10°C water.
- 8 Heat the last beaker of water to 35°C on the hot plate.
- 9 Repeat steps 3–5 for the 35°C water.
- 10 If you have time, you can repeat this for cooler or hotter temperatures as directed by your teacher.

RESULTS

- 1 Record your results in a table like Table 9.6.1. Include as many rows as you need for the temperatures you used in the experiment.

▼ TABLE 9.6.1

Temperature (°C)	Mass of solute added

- 2 Calculate the solubility of the salt at different temperatures, using the information in Module 9.3.

ANALYSIS

- 1 Create a graph to show how the mass of solute added changes as the temperature increases. Consider the most appropriate type of graph and include axis labels, a title and a line of best fit.
- 2 Describe the trend your graph shows about the solubility of sugar as the temperature increases.
- 3 Describe the variables that you controlled in this experiment and justify why they were controlled.
- 4 Using particle theory (as described in Chapter 8), propose reasons for any changes you observed.

DATA SCIENCE



Learn more about identifying trends in data in **Module 2.8**.

9.7 Types of mixtures: suspensions

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define suspension
- ✓ describe the structure and properties of suspensions.



Quiz

What is a suspension?

GET THINKING

Think about what happens when dirt is added to a bucket of water.

- Does the dirt dissolve?
- What happens if you leave it for an hour?
- What do you think happens to the dirt particles?
- Why do you think this happens?

The structure and properties of a suspension

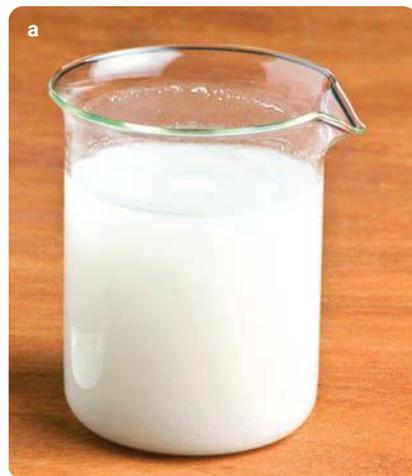
Not all mixtures are solutions. If the substance being added to a solvent is not soluble, then it will not dissolve. This means that the mixture that is produced is not a solution. Instead, a **suspension** or a colloid is formed. In this module, you will learn about suspensions.

A suspension is formed when an insoluble substance is added to the solvent. Although it may initially spread throughout the solvent, if it is left for a while the substance settles to the bottom of the container (Figure 9.7.1).

Adding dirt to water produces a suspension. Initially, the water looks dirty throughout because the dirt particles are mixed with the water. However, if the mixture is left, the dirt will settle to the bottom. This means that the suspension forms layers.

suspension

a mixture of at least one insoluble solid and a liquid or solution, where the insoluble substance settles to the bottom of the container over time



MARTYN F. CHILLMAID/Science Photo Library



GIPhotoStock/Science Photo Library

▲ FIGURE 9.7.1 (a) Powdered chalk added to water and mixed will form a suspension. (b) If the suspension is left undisturbed, the chalk will settle to the bottom of the beaker.

Sometimes it is difficult to know whether the mixture is a solution or a suspension. The key difference is that a solution is usually transparent because the substance has dissolved. In a suspension, the substance did not dissolve and therefore it can still be seen. This means that when the suspension is mixed, it is not transparent. A second way to tell the difference is that a suspension will settle into layers, but a solution will not. This is because the substance in a suspension is too heavy to stay **suspended** in the liquid.

suspended

hanging or keeping from falling

Understanding the appearance of beach water in different weather conditions

On a calm day, the water at the beach can be crystal clear, as in Figure 9.7.2. However, when the weather is windy, the water can be opaque and dirty, as in Figure 9.7.3.



iStock.com/penkanya



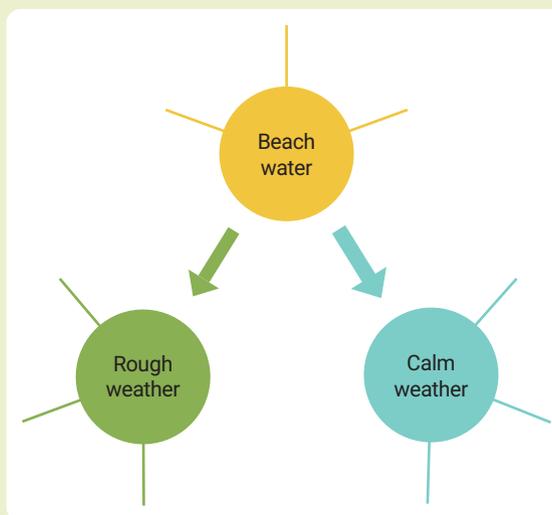
iStock.com/Susan Vineyard

▲ FIGURE 9.7.2 Crystal clear ocean water

▲ FIGURE 9.7.3 Dirty beach water

We can use our understanding of the structure and properties of suspensions to explain the beach water in each of these situations.

- 1 Brainstorm the reasons for the different appearances of the beach water. Use the template in Figure 9.7.4 to create a mind map with your ideas.
- 2 Make a model of the beach water by putting some sand and water in a large beaker. How will you replicate calm weather or rough weather?
- 3 Use your brainstorm, model and information in this module to write a paragraph explaining the appearance of beach water in different weather conditions.



▲ FIGURE 9.7.4 A template for a mind map

9.7 LEARNING CHECK

- 1 **Define** suspension.
- 2 **State** the property that determines whether a substance will form a suspension, and not a solution, when added to water. **Justify** your answer.
- 3 **List** two examples of suspensions.
- 4 Calcium carbonate is insoluble in water. During an experiment to observe mixtures, a student added a spatula of calcium carbonate powder to water in a beaker. The mixture was stirred with a stirring rod and then left undisturbed for an hour. **Describe** the predicted observations:
 - a when the mixture was first stirred.
 - b after the mixture had been left for an hour.

9.8 Types of mixtures: colloids

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define colloid, Tyndall effect, emulsion, foam, gel and aerosol
- ✓ explain the structure and properties of colloids.

GET THINKING

Observe the glass of milk in Figure 9.8.1. Is milk a solution or a suspension or neither? List the characteristics of milk that correspond to solutions and the characteristics that correspond to suspensions. Use this to justify your answer.



Anton Stanikov/Shutterstock.com

▲ **FIGURE 9.8.1**
Is milk a solution or a suspension, or neither?

colloid

a mixture of two or more insoluble substances that remains evenly mixed and does not settle over time

opaque

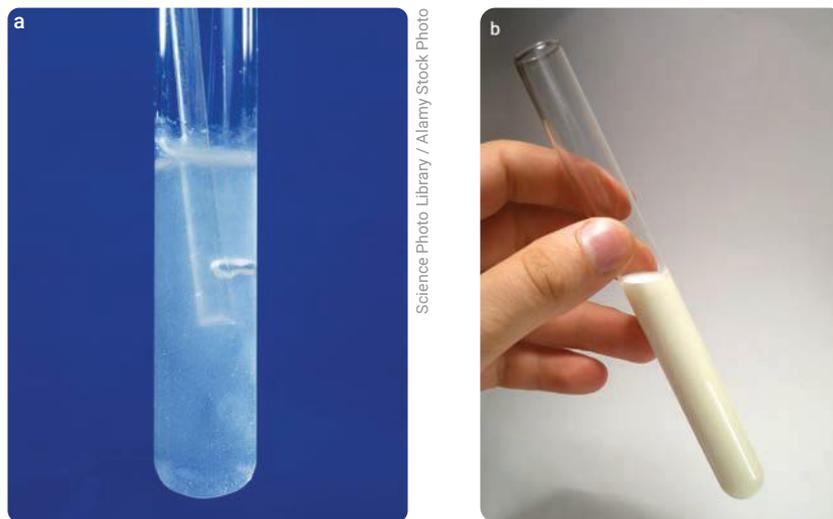
cannot be seen through

The structure and properties of a colloid

A **colloid** is another type of mixture. A colloid is similar to a suspension because it forms when an insoluble substance is added to a solvent. However, in the case of a colloid, the particles are so small that they do not settle to the bottom. Instead, they stay spread out in the mixture.

Ink is a colloid. It has solid pigment particles spread evenly in a liquid such as oil or water. Ink is not a solution because the solid pigment particles do not dissolve in the oil or water. It is not a suspension either because the mixture does not settle into layers. Other examples of colloids are milk, mayonnaise, smoke, paint, whipped cream and blood.

The particles in a colloid are larger than the particles in a solution and so the mixture is cloudy, or **opaque**, rather than transparent. The number of insoluble particles affects how cloudy the colloid is. A colloid with many insoluble particles is more opaque than one with a smaller number of insoluble particles (Figure 9.8.2).



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iStock.com/imelchion

▲ **FIGURE 9.8.2** Test tubes of colloids. (a) This test tube has fewer insoluble particles, and so is less opaque, than (b) this test tube, which has more insoluble particles.

Tyndall effect

when the insoluble particles in a colloid scatter a beam of light, enabling you to see the beam of light

It is possible to identify whether a mixture is a solution or a colloid by shining a thin beam of light through it. In most solutions, you will not be able to see the beam of the light. In a colloid, the insoluble particles will scatter the light, which means you will be able to see the beam of light. This is called the **Tyndall effect** (Figure 9.8.3).

Types of colloids

We can further classify colloids by looking at the different states of the substances that are mixed.

- **Foams** are formed when a gas is spread through a liquid; for example, whipped cream or shaving cream.
- **Emulsions** are a type of colloid containing only liquids. Both cream and homogenised milk are stable emulsions. They are cloudy white mixtures with liquid milk fat mixed evenly throughout liquid water. Cream is more opaque than milk because there is more milk fat mixed throughout the liquid water.
- **Gels** are formed when a solid is spread throughout a liquid; for example, jelly, paint or blood.
- **Aerosols** are formed when a solid or a liquid is spread through a gas. Hairspray is an aerosol that has a liquid spread through a gas. Smoke has solid ash particles spread through a gas (the air).



▲ **FIGURE 9.8.3** A beam of light is not visible through the solution on the left, but is visible through the colloid on the right. This is known as the Tyndall effect.

Science Photo Library/Alexandre Dotta/
Science Source

9.8

9.8 LEARNING CHECK

- 1 Copy and **complete** the table by **recalling** the components of different types of colloids.
- 2 **Describe** one method of differentiating (telling the difference between):
 - a colloid and a solution.
 - a colloid and a suspension.
- 3 **Classify** each of the following as solution, suspension or colloid.
 - Soft drink
 - Sand mixed in water
 - Pancake batter
 - The air near a bushfire
 - Ocean water
- 4 **Discuss** whether the orange juice in the photo is a solution, a suspension or a colloid. **Justify** your answer by referring to the properties of each of the types of mixtures.
- 5 Milk is a colloid. You can see the Tyndall effect for yourself if you add some drops of milk to water, darken the room and then shine a torch through the glass from the side. Take a photo that shows the Tyndall effect. **Annotate** your photo to **explain** why it occurs.

Type of colloid	What is spread in the colloid	What it is spread in
Foam		
	Solid	Gas
Aerosol	Liquid	
	Liquid	Liquid
Gel		



foam

a type of colloid in which a gas is mixed in a liquid

emulsion

a type of colloid in which a liquid is mixed in another liquid

gel

a type of colloid in which a solid is mixed in a liquid

aerosol

a type of colloid in which a solid or a liquid is mixed in a gas



Interactive resource

Crossword:
Solutions,
suspensions
and colloids

Drag and drop:
Solutions, suspensions
and colloids



Observing to make classifications

SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THIS SKILL:

- ▶ using observational skills to make classifications.

OBSERVING MIXTURES

AIM

To observe different substances and use the observations to make appropriate classifications

MATERIALS AND EQUIPMENT

- test tubes
- test-tube racks
- plastic droppers
- approximately 50 mL water
- small spatula or spoon
- stoppers for test tubes
- variety of substances, such as table salt, jelly crystals, methylated spirits, vinegar, olive oil, kerosene, sand, powdered chalk, milk, cream, small pieces of cork, tea leaves

PROCEDURE

In a group of two or three:

- 1 Construct a results table similar to Table 9.9.1. Your teacher will tell you what substances you will be testing – list these in the column with the heading ‘Substances’.
- 2 Place the test tubes in the test-tube rack and label each with the name of one of the substances.
- 3 Add a small amount of each substance to the relevant test tube. For solids, add about a spatula tip full. For liquids, use a clean plastic dropper to add liquid to a height of about 2 cm in the test tube.
- 4 Observe each substance, recording the physical properties in the results table.
- 5 Use a plastic dropper to add enough water to half-fill each test tube.
- 6 Place a stopper on each test tube and carefully shake it from side to side for 1 minute.
- 7 Observe each mixture, recording your observations in the results table.
- 8 Place each mixture in the test-tube rack and leave it for 15 minutes.
- 9 Observe each mixture, recording your observations in the results table.

Safety

Broken glass can cut skin. Use test-tube racks to hold test tubes. Clean up any broken glass immediately and put it in the glass bin.

Substances can get into your eyes and cause damage. Always wear safety glasses.

Some of the substances used in this experiment are flammable. Perform the experiment away from naked flames.

Some of the substances, such as kerosene, can be irritating to skin and respiratory surfaces. Wear protective clothing. Perform the experiment in a well-ventilated area.

RESULTS

Record your observations in your results table (Table 9.9.1).

▼ TABLE 9.9.1 Observations of different mixtures

Substance	Observations before water was added	Observations as soon as water was added	Observations after 15 min	Type of mixture

ANALYSIS

- Classify** each of the mixtures as a solution, suspension or colloid. **Record** your classification in the results table.
- Compare** your classifications with those of other groups in the class. Where there any differences? If there were, suggest a reason why.
- Explain** how your observations allowed you to classify each mixture.
- List** the variables in this experiment. Which of the variables were controlled? Which were not controlled?

- Explain** why the solutions were left for 15 minutes.
- Discuss** the concepts of pure substances and mixtures with reference to the mixtures you have made.

CONCLUSION

Write one or two sentences summarising the importance of making careful observations when classifying substances.

9.10 Air quality

BY THE END OF
THIS MODULE, YOU
WILL BE ABLE TO:

- ✓ explain how scientists use the concentration of pollutants as a measure of air quality.



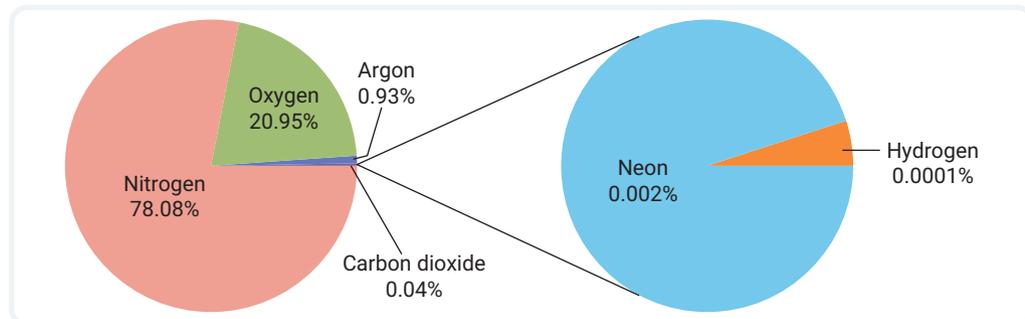
Video activity
Measuring air quality



iStock.com/Kaszojad

▲ FIGURE 9.10.1 Air pollution is a serious health issue.

Air is a mixture of gases such as nitrogen, oxygen, carbon dioxide, neon and hydrogen. Figure 9.10.2 shows the percentage of each gas normally found in air.



▲ FIGURE 9.10.2 The percentages of gases in air. These percentages do not add to exactly 100 because they have been rounded.

pollutant

a substance introduced into an environment that can be harmful

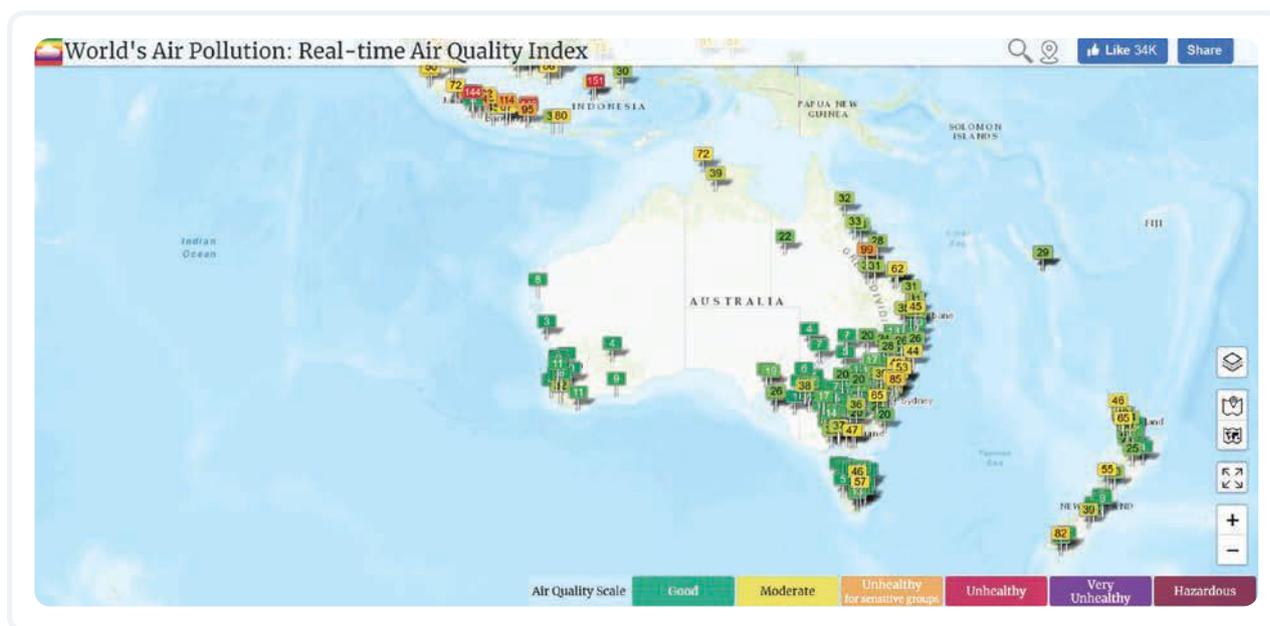
Unfortunately, there are also substances in the air that can be harmful. These are called **pollutants**. Some common pollutants are:

- carbon monoxide from vehicles and industry
- sulfur dioxide from power plants and industry
- nitrogen dioxide from vehicles, industry and gas heaters
- small particles in smoke from wood fire heaters and bushfires
- dust
- pollen.

air quality index (AQI)

a measure of the level of pollution in the air, expressed as a number from 0 (no pollution) to 500 (maximum pollution)

It is estimated that, during 2020, air pollution caused more than 6.7 million deaths across the world. Air pollution is especially noticeable in some very polluted cities, including Tokyo (Japan), Delhi (India), Mexico City (Mexico) and São Paulo (Brazil). Scientists have developed the **air quality index (AQI)**, which indicates the level of pollutants in the air. An AQI of less than 50 indicates that the level of pollution is



▲ FIGURE 9.10.3 The AQI across parts of Oceania and southern Asia in September 2024. Most places in Australia register as good or moderate on the scale.

low and is unlikely to affect most people's health. The higher the AQI, the higher the pollution levels and the greater the risk of harm to people's health.

By measuring the concentration of pollutants, scientists can monitor and communicate risks to the community. Many weather apps include the local AQI. Some government websites also report the AQI and provide advice for residents. Some websites also have a 'pollen forecast', which indicates how much pollen there is likely to be in the air. This means that people at higher risk (e.g. those with respiratory diseases) can take precautions such as staying inside. During windy spring days or when there are bushfires nearby, people should close windows and doors to keep pollutants such as pollen and smoke out of the house. Similarly, in Australia it is now illegal to smoke cigarettes in a car when there is a child present because the cigarette smoke, a pollutant, is a risk to the child.



Weblink
World's Air Pollution:
Real time Air
Quality Index



▲ FIGURE 9.10.4 The AQI is included in many weather apps.

9.10 LEARNING CHECK

- 1 What does AQI stand for?
- 2 **List** the following gases in order from the highest percentage in air to the lowest: carbon dioxide, oxygen, nitrogen, argon, neon, hydrogen.
- 3 **List** five pollutants that are commonly found in air.
- 4 **Explain** why air is classified as a mixture.
- 5 Amy suffers from asthma. She regularly checks the AQI for her suburb, especially when it is smoky outside. **Explain** how the AQI could help Amy avoid an asthma attack.
- 6 The AQI for Jakarta in Indonesia was 144 on 11 September 2024. **Discuss** why it would be advisable to wear a mask when outside.

9 REVIEW

REMEMBERING

- Write** the term that matches each description.
 - A pure substance whose particles have more than one type of atom
 - A mixture that is usually transparent
 - The substance that is dissolved in a solution
 - A pure substance whose particles are made up of only one type of atom
 - A mixture that separates into layers
 - The substance that does the dissolving in a solution
 - A mixture that allows a beam of light to be visible
- State** the term given to the physical property of being able to see through something.
- State** the name given to the substances that make an emulsion.
- Describe** the Tyndall effect and identify its use in classifying mixtures.
- State** whether each of the following statements is true or false. Rewrite each false statement to make it true.
 - Solutions are usually transparent.
 - Solutions are always colourless.
 - Fresh orange juice containing pulp is a solution.
 - A solution always has water in it.
 - When acetone removes nail polish, the nail polish is the solute and acetone is the solvent.
 - If soda water goes flat, it is no longer a solution. (You may need to research what soda water is made up of to answer this question.)
 - The particles in a colloid are smaller than in a suspension but larger than in a solution.
 - Water-soluble paint is a solution.
- Describe** the structure, at a particle level, of a:
 - pure substance.
 - mixture.

UNDERSTANDING

- Explain** why a suspension will separate into layers if left long enough, but a colloid won't.
- Explain** two ways you could tell the difference between a solution, a suspension and a colloid in the laboratory.

- A teaspoon of salt was added to a glass of hot water and stirred.
 - Describe** what you would observe.
 - Explain** why this occurs.
 - State** the:
 - type of mixture the salt and water forms.
 - name of the salt.
 - name given to the water.
 - If you kept adding more teaspoons of salt to the glass of water, do you think the salt would continue to dissolve? **Explain** your answer.
- Identify** whether each of the following statements is true or false. If it is false, **explain** why it is false.
 - In a suspension, particles always fall to the bottom of the container.
 - All emulsions are colloids.
 - All colloids are emulsions.
 - A suspension cannot contain a solution.

APPLYING

- During an experiment, Adam forgot to label his beakers of a blue solution produced when he dissolved copper sulfate in water. Adam knows that one solution is unsaturated, and the other is saturated. **Describe** two different methods that he could use to correctly identify each solution and the observations that he would make for each beaker. **Explain** why each observation occurred.
- Use the words 'dilute' and 'concentrated' to **describe** the two glasses of cordial shown.



© Cengage

- 13** Is a lake an example of a suspension? **Explain** your answer.
- 14** To make a simple form of tempera paint, egg yolk is added to a mixture of solid pigment and oil.
- Predict** which type of colloid the paint is.
 - Suggest** a reason why the egg yolk is needed.

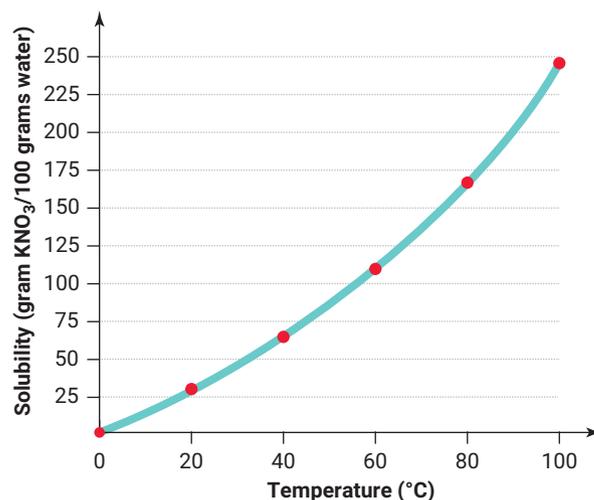
EVALUATING

- 15** Ming is testing three pure substances (A, B and C), which are all solids. She prepares three beakers, each with 100 mL of water at the same temperature. Ming adds 50 g of substance A (in 10 g amounts) to the first beaker and stirs the mixture. She repeats this for the other solids and beakers. Ming's observations are shown in the table. **Classify** the types of mixtures she created when she added A, B and C to the water. **Explain** the reasons for each classification.

Substance	Observations when mixed with 100 mL of water
A	As each 10 g amount is added, it dissolves instantly. After all the solid has been added, it is no longer visible. The mixture is transparent.
B	As each 10 g amount is added, the solid floats in the water. After 20 minutes, the solid has settled to the bottom of the container. None of the solid has dissolved.
C	Each 10 g amount seems to mix immediately. The mixture is not transparent. It does not separate into layers. After 20 minutes, there is still only one cloudy layer.

- 16** The solubility of potassium nitrate (KNO_3) is shown in the following graph.

- How many grams of potassium nitrate can dissolve in 100 g of water at 60°C ?
- If 50 g of potassium nitrate was stirred into 100 g of water at 40°C , would the solution be unsaturated, saturated or supersaturated? **Justify** your answer.
- What mass of potassium nitrate should be added to 200 g of water at 20°C to produce a saturated solution? **Explain** the reason for your answer.
- If 150 g of potassium nitrate needs to be dissolved in 100 g of water, what temperature should the water be heated to?



- 17** The saying 'clear as mud' is used when you try to explain something to someone, but they do not understand straight away.
- State** what type of mixture mud is.
 - How does this saying suggest that you do not understand what is being explained?
 - Using a different mixture, **write** a saying you could use if you understand an explanation straightaway. **Explain** how your saying achieves this.

CREATING

18 Construct a question that has the answer of:

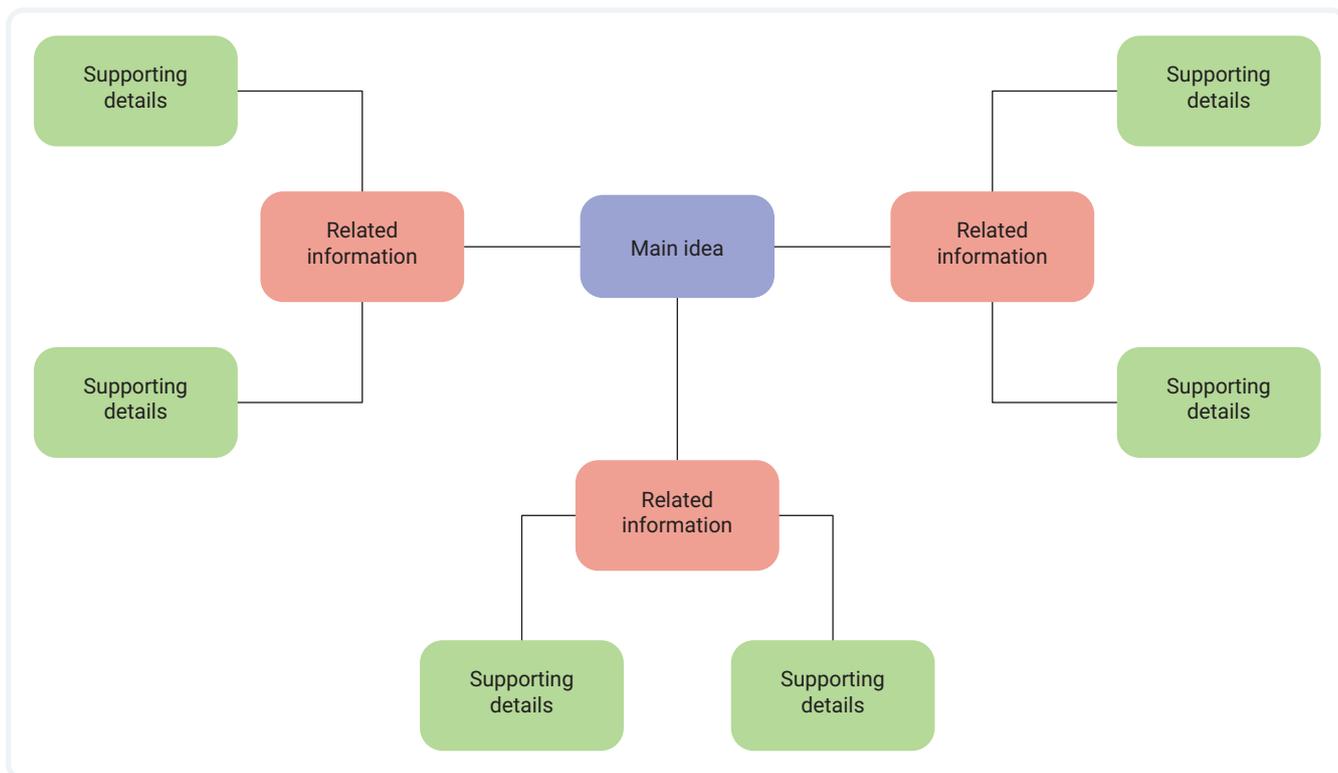
- | | |
|-----------------------|--------------------|
| a dissolve. | b soluble. |
| c solute. | d solution. |
| e solubility. | f dilute. |
| g unsaturated. | |

19 In this chapter, you have learned about a lot of different ways of classifying mixtures. **Create** a concept map (a mind map) to organise the information. Include the key terms in boxes or circles, using colours to show similarities or differences. Join the boxes or circles with linking lines to show the connection between terms. Complete your concept map by adding notes for definitions, diagrams and examples. The following diagram shows a simple structure for a concept map.

20 When you make a glass of cold Milo, you usually end up with a glass of chocolate-flavoured milk and a layer of solid Milo on top. **Create** an explanation of the composition of a glass of cold Milo by using the terms 'matter', 'pure substance', 'mixture', 'solution', 'suspension' and 'colloid'.



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Just like us, fish need oxygen. However, unlike us, fish can get their oxygen from water. Some oxygen from the air dissolves in the water, and fish have gills that can extract the oxygen from the water.

The amount of oxygen dissolved in the water varies depending on conditions such as temperature, aeration and salinity. People who keep fish in an aquarium or a pond need to monitor the levels of dissolved oxygen to make sure that there is enough oxygen for the fish.

1 Connect what you've learned

Write a paragraph explaining what dissolved oxygen in an aquarium is. Use relevant scientific terminology such as 'pure substance', 'mixture', 'solution', 'solute', 'solvent' and 'concentration' in your explanation.

2 Check your thinking

Conduct research to learn about the effect temperature, aeration and salinity have on levels of dissolved oxygen. Summarise your findings in a table similar to the one below.

▼ The effect of environmental factors on dissolved oxygen levels

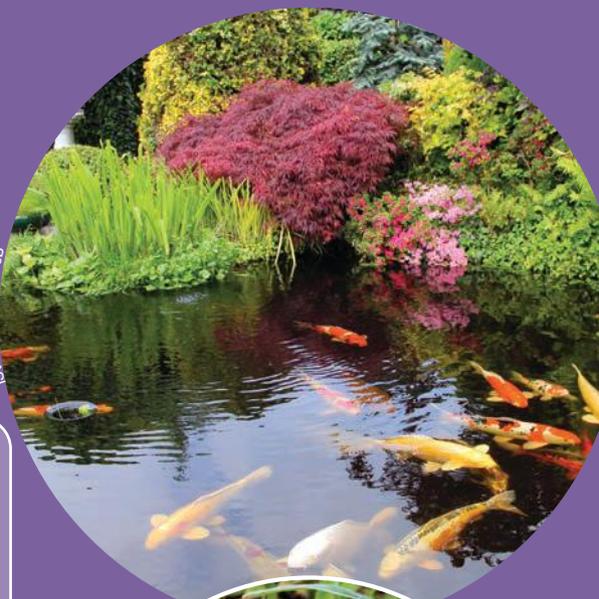
Factor	Does dissolved oxygen increase or decrease when the factor is increased?	Does dissolved oxygen increase or decrease when the factor is decreased?
Temperature		
Aeration		
Salinity		

3 Get into action

What steps do people with aquariums or ponds take to increase the levels of dissolved oxygen?

4 Communicate

Create an infographic to outline how to maintain an appropriate level of dissolved oxygen in an aquarium or a pond. The infographic should be suitable for people who have never owned fish before, so it needs to be clear and interesting.



▲ Fish have gills to extract oxygen from water.

10

Separating mixtures

10.1 Physical properties (p. 356)

Substances in a mixture have different physical properties.

10.2 WORKING SCIENTIFICALLY: **Writing a method** (p. 359)

Testing substances to determine physical properties

10.3 Separating suspensions: **filtration** (p. 361)

Filtration separates a suspension based on particle size.

10.4 Separating suspensions: **sedimentation, centrifuging and decanting** (p. 364)

Sedimentation, centrifuging and decanting are different ways of separating suspensions.

10.5 Separating solutions: **evaporation, crystallisation and distillation** (p. 368)

Evaporation, crystallisation and distillation are different ways of separating solutions.

10.6 Other separation techniques: **magnetic separation, flocculation and chromatography** (p. 373)

Magnetic separation, flocculation and chromatography are techniques used to separate mixtures.

10.7 WORKING SCIENTIFICALLY: **Chromatography** (p. 376)

Using chromatography to separate a mixture

10.8 WORKING SCIENTIFICALLY: **Problem-solving strategies** (p. 377)

Design your own experiment to separate a mixture

10.9 ABORIGINAL AND TORRES STRAIT ISLANDER SCIENCE CONTEXTS: **Traditional separation techniques** (p. 379)

For thousands of years, Aboriginal and Torres Strait Islander Peoples have used a variety of techniques to separate out parts of mixtures.

10.10 SCIENCE IN CONTEXT: **Separation techniques used in recycling** (p. 382)

During recycling, materials are broken down and made into new products.



iStock.com/Kokkai Ng

Rainwater flows into river systems and collects in dams and weirs such as Oberon, Hume and Glennies Creek dams in regional areas of New South Wales. This water is not safe for drinking or cooking and must be purified before we can use it.

Water treatment plants use a range of chemical and physical processes to remove solid particles, chemicals, bacteria and other microbes before the water reaches your house.

- ▶ What types of substances do you think you might find in the dam water before it is purified?
- ▶ Do you know what happens if you drink water containing pollutants or dangerous bacteria?

▲ **FIGURE 10.01** Much of the water supplied to homes in Sydney, Goulburn and the Southern Highlands comes from Warragamba Dam.

#10 DIVE INTO SCIENCE!

At the end of this chapter, you can complete Science in Depth Study #10. You can use the information you learn in this chapter to complete the project.

Assessments

- Prior knowledge quiz
- Chapter review questions
- End-of-chapter test
- Depth study: Science investigation

Videos

- Science skills in a minute: Methods (10.2); Problem solving in science (10.8)
- Video activities: Density of solids (10.1); Centrifuging blood plasma (10.4); Salt: separating mixtures (10.5); Fractional distillation (10.5); How recycling works (10.10)

Science skills resources

- Science skills in practice: Writing a method (10.2); Problem solving (10.8)
- Extra science investigations: Evaporation to separate a salt solution (10.5); Does ink contain water? (10.6)

Interactive resources

- Drag and drop: What is filtration? (10.3)
- Label: Lab equipment used to separate mixtures (10.5)
- Crossword: Separating substances (10.6)
- Simulation: Density (10.1)



10.1 Physical properties

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define physical property, solubility, melting point, boiling point and density
- ✓ describe the physical properties of substances.



Video activity
Density of solids

Interactive resource
Simulation: Density

GET THINKING

Observe the photo of sugar and flour in Figure 10.1.1. Think about what you know about sugar and flour. Write a list of the properties of each substance – what properties do they have in common and what properties are different?



▲ FIGURE 10.1.1 How are sugar and flour similar and how are they different?

Physical properties of chemical substances

chemical property

a property of a substance that shows how it reacts when combined with other substances

physical property

a property of a substance that can be observed or examined without changing the composition of the substance

Just as people have different features, so do chemical substances. These features are called properties. There are two types of properties: **chemical properties** and **physical properties**. Chemical properties relate to how a chemical changes to produce new substances. Physical properties, such as colour and hardness, are features that do not involve a change in the chemical. This module will focus on physical properties.

In Chapter 9, you learned that a mixture contains more than one type of substance. Because these substances are not combined chemically, we can use simple methods to separate them. Each method is based on a particular physical property that is different for the substances in the mixture. This can be compared to separating school students into classes on the basis of their different ages. In this module, you will learn about the different physical properties so that you can apply them in the following modules about separating mixtures.

Colour

The colour of a substance is a physical property. You may be able to use the colour of a substance to identify what it is made up of. For example, if a cake is brown, then you could infer that there is cocoa in it and therefore it is a chocolate cake. Or if your drink is yellow, then it might be lemon flavoured. Some chemicals are also coloured. Gold metal has a characteristic yellow colour, whereas copper metal is described as salmon pink. A solution of copper sulfate is blue, whereas a solution of potassium permanganate is purple–pink (Figure 10.1.2).



▲ FIGURE 10.1.2 Some solutions have distinct colours, such as copper sulfate (blue), nickel sulfate (green) and potassium permanganate (purple–pink).

Sometimes, the colour determines what chemical is chosen for a particular purpose. Aboriginal and Torres Strait Islander artists used their knowledge of the colour of substances well before modern paints were available. If the artist wanted an orange paint, they mixed ochre clay with water because it contains iron oxide, which gives it an orange colour. Or if they wanted black, the artist would use charcoal.

Transparency

Transparency refers to whether you can see through a substance. If you can see through something, it is **transparent**. If you cannot see through it, it is described as **opaque**.

A glass window is fully transparent because you can see through it. A brick wall is opaque because you cannot see through it. Some chemical substances, such as white vinegar, are transparent. By contrast, others, such as copper metal, are opaque.

In Chapter 9, you learned that solutions are generally transparent, but colloids are not. Therefore, the physical property of transparency may be used to identify whether a liquid is a solution or a colloid.

Soluble or insoluble

Whether something is soluble or not (insoluble) is another physical property. It could be easy to think that this is a chemical property because the solid has disappeared when it dissolves. However, it is still the same chemical, just spread out into particles that are so small we can't see them anymore. This means that being able to dissolve (or not dissolve) is a physical property.

immiscible

describes liquids that are unable to mix; they separate into layers if combined

Density

In Chapter 8, you learned that **density** is how much mass there is in a certain volume. In fishing, a lead sinker is used to take the fishing line down through the water. It does this because lead is dense – it is heavier than most other substances that are the same size. A marshmallow is not very dense – it is lighter than most other substances of the same size.

When two **immiscible** substances are combined, they do not mix. The less dense substance rises and sits on top while the denser substance sinks and sits on the bottom. This is why oil forms a layer on top of water – it is less dense than water (Figure 10.1.3).



▲ **FIGURE 10.1.3** Oil forms a layer on top of water because it is less dense than water. Oil and water are immiscible substances.



▲ FIGURE 10.1.4 Water at boiling point

Melting and boiling points

In Chapter 8, you learned about changes of state. The **melting point** is the temperature at which a substance changes between a solid and a liquid when it is melting or freezing. Similarly, the **boiling point** is the temperature at which all of a substance changes between a liquid and a gas when it boils or condenses.

Melting and boiling points are important physical properties because they determine the state of matter that a substance normally exist as. For example, water has a melting point of 0°C and a boiling point of 100°C . Therefore, water is a liquid at room

temperature (approximately 25°C) because the temperature is high enough for the water to melt, but not high enough for it to boil.

Other physical properties

Other physical properties include:

- **lustre** – how much a substance reflects light. If something is shiny, such as diamond, then it is described as lustrous. If a substance such as wood is not shiny, then it is described as dull
- **viscosity** – a liquid's resistance to flowing. Liquids that are thick and sticky, such as honey, have a high viscosity. Liquids that flow easily, such as water, have a low viscosity
- texture – what something feels like; for example, smooth or rough
- magnetism – being attracted to a magnet
- smell – for example, no odour, sweet smelling or pungent (a strong, sharp smell)
- hardness – for example, soft, brittle or hard.

lustre

how shiny a metal is

viscosity

a liquid's resistance to flowing

10.1 LEARNING CHECK

- 1 **List** five physical properties of water.
- 2 **Explain** why taste is not included in the physical properties of chemicals in a science laboratory.
- 3 **Compare** the physical properties of milk and lemonade. **State** two physical properties that they have in common and two physical properties that are different.
- 4 Physical properties can be classified as extrinsic or intrinsic. An extrinsic property changes depending on the amount of the substance (e.g. mass, volume, height or length), whereas an intrinsic property does *not* depend on the amount of the substance, such as density and boiling point, and will always stay the same. Do you think intrinsic properties or extrinsic properties are more valuable when describing chemicals? **Justify** your answer.
- 5 **Create** a table to **summarise** the description and examples for the physical properties covered in this module.



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ testing a range of substances for different physical properties
- ▶ planning a procedure and writing a method.

As you learned in Chapter 1, a scientific method describes what you did to collect your data during an investigation. It is slightly different from a procedure, which is the steps you are planning to do. During an investigation, it is common for the steps to be changed. Therefore, the method is a more accurate representation of what was done.

When you write a method, it should be:

- written in numbered steps to show the order that you did things
- clear and easy to understand
- detailed, so that others can repeat what you did, including equipment used, types of measurements and units of measurement
- written in the past tense because it is something you did in the past
- written in the passive voice, so the focus is on what was done, not on the people who did it.

An example of a step from a method is:

- 1 100 mL of tap water was poured into the clean beaker.



Video
Science skills in a minute: Methods

Science skills resource
Science skills in practice: Writing a method

TESTING SUBSTANCES TO DETERMINE PHYSICAL PROPERTIES

AIM

To test a range of substances to determine their physical properties

MATERIALS AND EQUIPMENT

- ☑ a range of substances provided by your teacher, such as salt, metals, polystyrene and plastics
- ☑ 250 mL beakers
- ☑ bar magnet
- ☑ ask your teacher about other equipment you could use, such as a container of water, light sources or an electronic balance.

PROCEDURE

- 1 Collect a sample of each substance provided by your teacher.
- 2 You will test each substance for the following physical properties:
 - solubility
 - density
 - colour
 - magnetism
 - transparency.
- 3 Colour and transparency (how much light passes through a substance) can be easily determined by observation. Make these observations and record the results in your results table.
- 4 In pairs, design a procedure to test each substance for solubility, density and magnetism. Check your procedure with your teacher before proceeding. See Chapter 8 for help with measuring density, and Chapter 9 for help with measuring solubility.
- 5 Test each substance for solubility and record your results in the table.
- 6 Measure the density of each substance and record it in g/L in the table.
- 7 Test each substance for magnetism and record your results in the table.

RESULTS

Record your results in a table like the one below. Add in the substances you tested in the first column.

ANALYSIS

- Once you have completed the experiment, write a formal method. Use the list provided at the start of this investigation to accurately record what you did in this experiment. Remember, there might be differences between the steps you planned in your procedure, and what you actually did when you conducted the experiment.
- Which physical properties are different between the substances tested?

- Which physical properties are similar between the substances tested?
- Compare your procedure and method to identify any differences between the two. By giving reasons, justify any differences between your plan (procedure) and your experiment (method).

CONCLUSION

Write a conclusion for your investigation. Were there any similarities between the properties of the substances tested? In what ways did the substances differ in their properties?

Substance	Soluble? (yes/no)	Density (g/L)	Colour	Magnetic? (yes/no)	Transparent? (yes/no)

10.3 Separating suspensions: filtration

10.3

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define filtering, filtration, filter funnel, filter paper, filtrate and residue
- ✓ label the components of a filtration apparatus
- ✓ explain how filtration separates the components in a suspension.

GET THINKING

When you are shopping online, you may use filters to refine your search. In small groups, discuss the purpose of these filters and how they work. Summarise your discussion in a few sentences, including an example. As you work through this module, reflect on your discussion and how filtering in science is similar to filtering while online shopping.

Get Tech-ready for school – Tablets

Sort by: **Low to High** ▼ Image per page **10 20 30**

Search Category

- Tablets
- Education tools
- Smartphones

Refine by

Price –

- \$150–200
- \$200–250
- \$250–300
- \$300–350
- \$350–400

Filters

			
\$200	\$300	\$299	\$400
			

▲ **FIGURE 10.3.1** You use filters when shopping online.

Filtration

Filtration is a technique that separates mixtures based on the size of the particles. When scientists are **filtering**, they use a filter such as **filter paper**, which has very small holes (or pores). Particles that are smaller than the holes will pass through the filter paper and form the **filtrate**. Particles that are bigger than the holes will not pass through. They are left on the filter paper and form the **residue**.

Suspensions can be separated by filtration. The solid particles are too big to pass through filter paper but the particles dissolved in the liquid are small enough to pass through. Filtration will not separate a solution or colloid because all the particles are small enough to pass through the filter paper.

We use filters every day. Vacuum cleaners contain dust bags with small pores that trap the solid dust particles but let the air pass through. You use a sieve to remove lumps from flour when baking. Clothes dryers have a filter that traps lint so that it doesn't end up all over your clothes.



filtration

a process used to remove solid substances from a liquid or gaseous mixture based on differences in the size of particles

filtering

performing the process of filtration

filter paper

paper with very fine holes (pores) that allow only very small particles to pass through

filtrate

the substance that passes through the filter paper, usually a liquid

residue

what is left in the filter paper after filtration

◀ **FIGURE 10.3.2** Filtration produces a filtrate and a residue.

filter funnel

a funnel used to hold filter paper during filtration

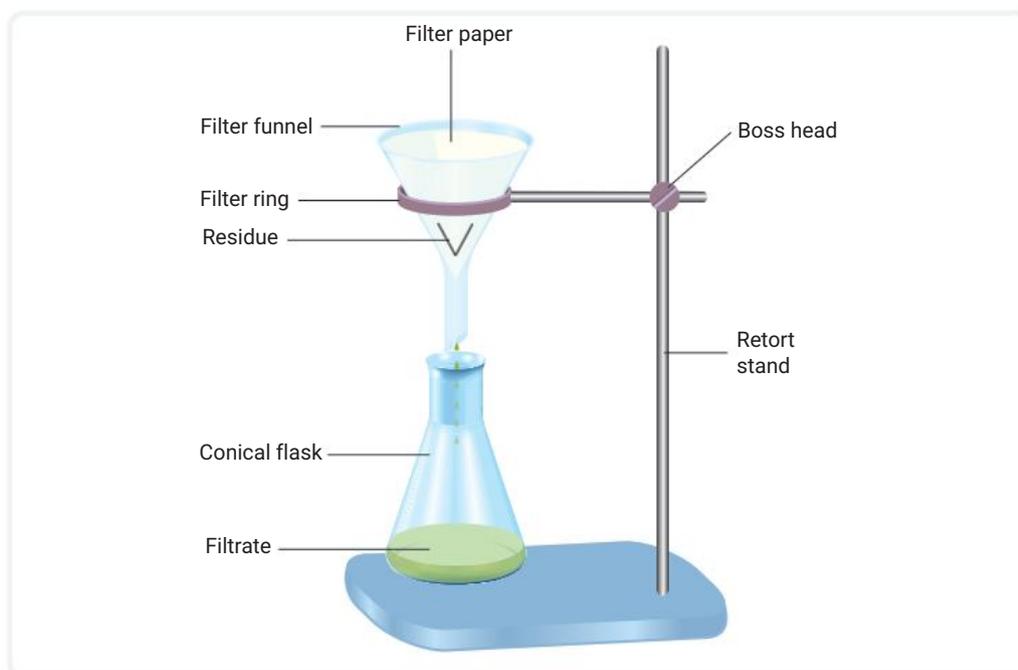


Interactive resource
Drag and drop: What is filtration?

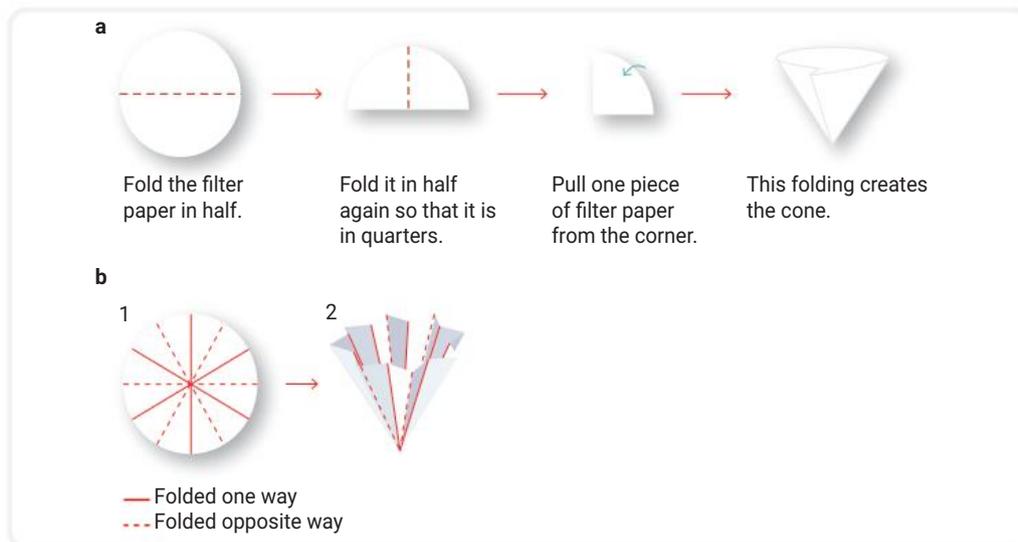
Extra science investigation
Filtration to separate sand from water

In a laboratory, a **filter funnel** is used to hold the filter paper. The funnel may be supported by a funnel ring attached to a retort stand (Figure 10.3.3), or it can sit in the top of a conical flask. The filter paper is carefully folded (Figure 10.3.4) to sit inside the funnel and the mixture is poured into the filter paper. For the filtration to be successful, all of the mixture must go through the paper and not around or through holes in the paper. Therefore, it is important that the:

- mixture does not come to the top of the filter paper
- filter paper is not creased too much
- filter funnel and paper are balanced and not tilted
- filter paper has no tears in it.



▲ FIGURE 10.3.3 A filtration apparatus used in the laboratory



▲ FIGURE 10.3.4 Two methods of folding filter paper: (a) traditional and (b) fluted

Separating a suspension by filtration

☆ ACTIVITY

10.3

Materials and equipment

- mixture of water, calcium carbonate and marbles (approximately 200 mL)
- strainer
- filter paper and filter funnel
- 250 mL conical flask
- 500 mL beaker

Procedure

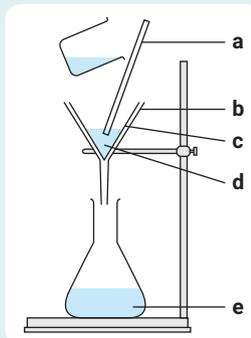
- 1 Place the strainer above the beaker.
- 2 Pour the mixture into the strainer.
- 3 Fold the filter paper in one of the ways shown in Figure 10.3.4 and place it in the filter funnel.
- 4 Sit the funnel in the top of the conical flask and pour the mixture from the beaker into the funnel.

Analysis

- 1 What part of the mixture was collected in the:
 - a strainer?
 - b conical flask?
 - c filter funnel?
- 2 Why wasn't the calcium carbonate separated from the water by the strainer, but the marbles were?

10.3 LEARNING CHECK

- 1 **Label** the parts of the filtration set-up shown.
- 2 **State** which physical property is used to separate mixtures by filtration.
- 3 Chloe is filtering a mixture of sand and water.
 - a What will be in the filtrate? **Explain** your answer.
 - b What will be in the residue? **Explain** your answer.
- 4 After cooking rice in a saucepan, it is strained to remove the water. **State** one similarity and one difference between straining the rice and filtering a suspension using filter paper.
- 5 **Explain** why filtration will not separate the salt and water in ocean water.
- 6 Challenge: Ari made a blue copper sulfate solution by adding powdered copper sulfate to water until no more solid could dissolve. He then poured the mixture through filter paper and was surprised to see blue solid copper sulfate as a residue.
 - a Where would Ari have seen the residue?
 - b What colour would the filtrate have been? **Explain** your answer.
 - c **Suggest** why Ari was surprised to see the solid.
 - d **Explain** why there was copper sulfate residue. (Hint: Review Chapter 9.)



10.4

Separating suspensions: sedimentation, centrifuging and decanting

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define sedimentation, centrifuging, decanting and decantation
- ✓ state the property that allows sedimentation, centrifuging and decanting to separate mixtures
- ✓ explain how sedimentation, centrifuging and decanting separate mixtures.



Video activity
Centrifuging blood plasma

GET THINKING

Look at the pictures in this module. What word describes each action that is occurring? As you learn about each separation technique, relate the information to this word. By linking new information to something you already know, you are more likely to remember it!

sediment

the insoluble solid that settles on the bottom of a suspension

sedimentation

the process of particles settling on the bottom of the liquid part of a suspension

centrifuging

the process of using a centrifuge to separate a mixture

centrifuge

a machine that spins very fast and separates heavier substances from lighter substances

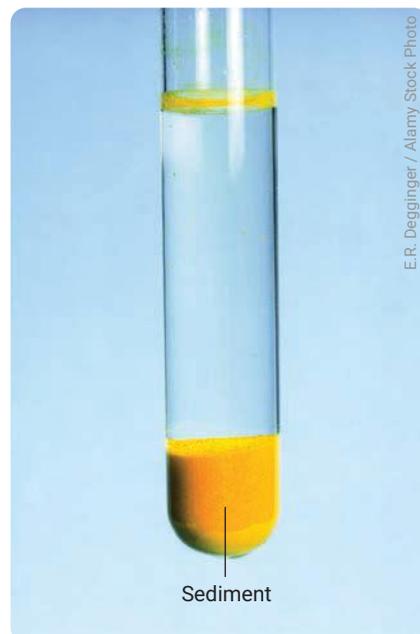
Sedimentation

When a suspension has been left for a while, the insoluble substance separates from the liquid. If the solid is dense enough, it settles on the bottom (Figure 10.4.1). This solid is called the **sediment** and the process is called **sedimentation**. You can see sedimentation after soaking dirty clothes. If you leave the water in the sink, the dirt will settle on the bottom, leaving clear water above it.

Centrifuging

Sedimentation can be a slow process because it relies on gravity to separate the mixture into layers. **Centrifuging** is used to quickly separate a suspension or colloid into layers based on the density of the substances.

A **centrifuge** is a machine that spins very fast, like a washing machine on its spin cycle (Figure 10.4.2.). As it spins, the denser substance moves to the sides of the container. Some centrifuges also include a filter that allows only the smaller substances through. A washing machine works in this way. As it spins, the wet clothes are pushed to the sides of the drum. The holes on the outer wall allow only the water to pass through, and so the water is separated from the clothes. In the kitchen, a lettuce spinner works in the same way. As it spins, the wet lettuce is pushed to the sides of the spinner and the water passes through the holes, leaving the lettuce dry.



E.R. Degginger / Alamy Stock Photo

▲ **FIGURE 10.4.1** During sedimentation, a heavy sediment settles on the bottom of the container.



▲ FIGURE 10.4.2 A centrifuge spins very quickly to separate the mixtures in the tubes.

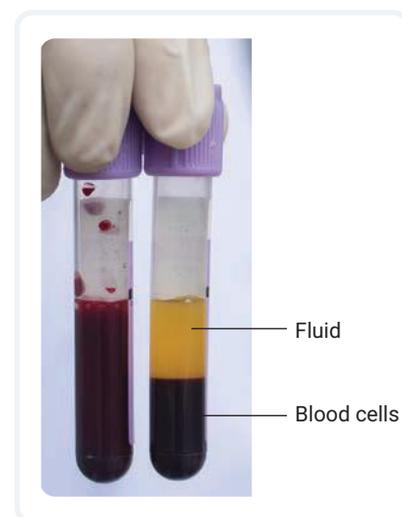
Laboratory centrifuges hold special tubes containing the mixture. As the tubes spin, the denser substance goes to the bottom of each tube. When the spinning is finished, the mixture has been separated into layers. Doctors, veterinarians and medical scientists use this technique to separate the parts of blood samples (Figure 10.4.3). This allows them to determine how much of the blood is fluid and how much is cells.

Decantation

Decantation is the process of pouring off a liquid. Decantation can separate mixtures that form layers, such as a suspension of dirt in water, or immiscible liquids such as oil and water. Pouring off the top layer separates it from the rest of the mixture.

Decanting is often used in everyday life. For example, once you have cooked potatoes or vegetables in boiling water, you can carefully pour the water out of the saucepan, leaving the potatoes or vegetables in the saucepan.

Decanting is not a very precise way to separate a suspension: it can stir up some of the solid particles and these may be poured out with the liquid. For this reason, the last bit of liquid is usually left in the container with the sediment and not all the solid is recovered.



▲ FIGURE 10.4.3 Blood before centrifuging (left) and after centrifuging (right). Centrifuging separates the blood into layers.

decantation
the process of decanting

decanting
pouring off the top, less-dense liquid

In the laboratory, a stirring rod can direct the fluid as it is being poured off. This is shown in Figure 10.4.4.



Shutterstock.com

▲ FIGURE 10.4.4 Decanting a suspension

☆ ACTIVITY

Separating a suspension by decantation

You need

- dirt
- water
- 2 × 250 mL beakers
- 100 mL measuring cylinder
- stirring rod
- teaspoon

What to do

- 1 Measure 100 mL of water in the measuring cylinder.
- 2 Pour the water into one of the beakers.
- 3 Add a teaspoon of dirt to the water and stir it with the spoon until it is evenly mixed.
- 4 Describe the mixture.
- 5 Leave the mixture overnight.
- 6 Describe the mixture the next morning.
- 7 Decant the water into the second beaker, using the stirring rod to direct the flow. Stop decanting before the dirt layer.
- 8 Measure the volume of clean water with the measuring cylinder.

What do you think?

- 1 Compare your descriptions of the mixture from steps 4 and 6. Explain why they are different.
- 2 Your mixture started with 100 mL of water. Why weren't you able to decant all of the water from the mixture?

10.4 LEARNING CHECK

1 Define:

- a sediment.
- b centrifuging.
- c decantation.

2 **State** which physical property is used to separate mixtures by centrifuge or decantation.

3 **Describe** the process of decantation.

4 **State** a disadvantage of decantation.

5 **Explain** the advantage of centrifuging over sedimentation.

6 In the carnival ride shown, people are strapped in around the edge of the ride, which spins very fast.



a **Describe** what the people would feel during the ride.

b **Compare** this to a centrifuge by stating one thing that is the same and one thing that is different.

7 Having visual aids can help us remember information. In this module, you learned about some different ways of separating mixtures. **Create** a poster for each method to summarise the key information. Use a clear diagram or photo as the main part of your poster, with labels and text boxes for other facts.

10.5

Separating solutions: evaporation, crystallisation and distillation

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define evaporation, crystallisation, distillation, distillate and condenser
- ✓ label the components of a distillation apparatus
- ✓ explain how evaporation, crystallisation and distillation separate mixtures
- ✓ compare evaporation, crystallisation and distillation.



Video activities

Salt: separating mixtures
Fractional distillation

Interactive resource

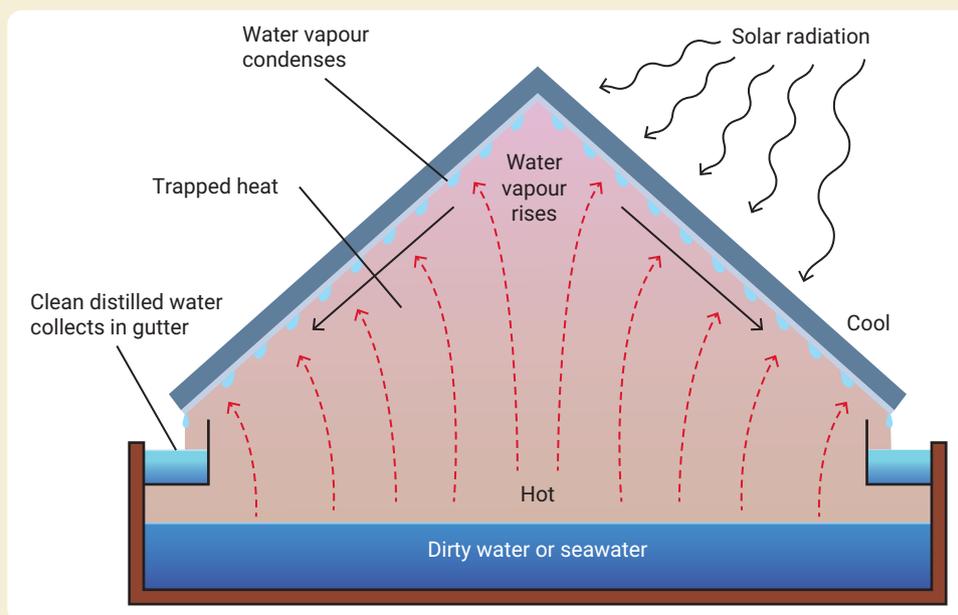
Label: Lab equipment used to separate mixtures

Extra science investigation

Evaporation to separate a salt solution

GET THINKING

A solar still is a device that uses energy from the Sun to obtain fresh drinking water from dirty water or salt water. Figure 10.5.1 is a diagram of a simple solar still. Use the labels to follow how the solar still works. Which changes of state are occurring? This same principle is used in the separation techniques in this module.



▲ FIGURE 10.5.1 A solar still

Separating solutions

Separating the parts of a solution relies on the different properties of the solute and solvent. When choosing a method, you need to think about which part, or parts, of the solution you want to collect in its pure form.

Evaporation

Evaporation is the process of a liquid changing into a gas. Unlike boiling, evaporation can happen at temperatures lower than the boiling point. For example, water will evaporate when the temperature is 25°C, even though its boiling point is 100°C.

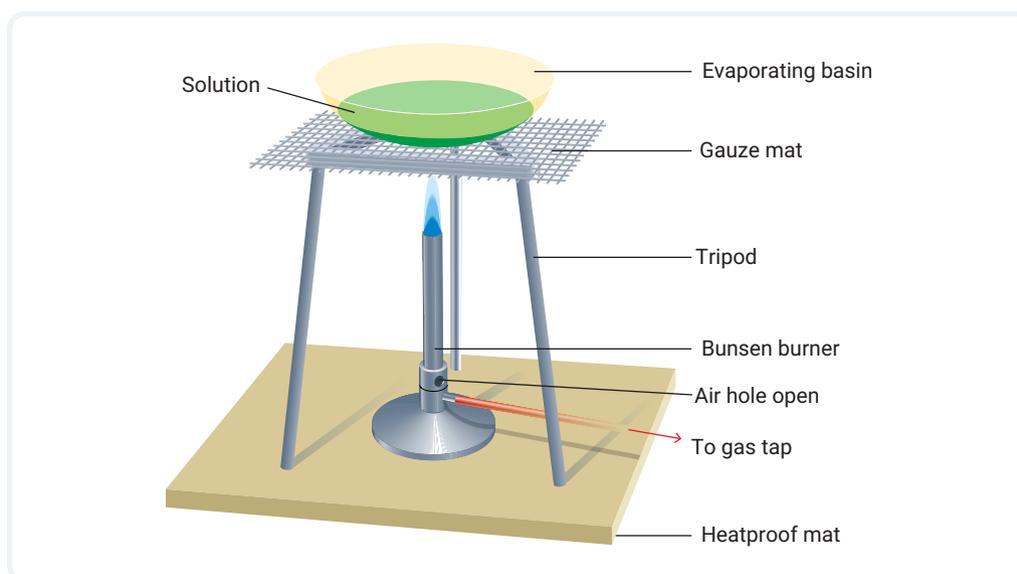
Evaporation can be used to separate the parts of a solution because one part will evaporate more easily than the other. In most cases, the solvent will evaporate to leave only the solute.

After a day at the beach, you will often find salt crystals on your skin. Seawater is a solution of salt and water. When the water evaporates, it leaves the salt behind, which you see as salt crystals. On a hot day, this happens more quickly because the water can evaporate at a faster rate. Around the world, salt evaporation ponds are used to collect salt from seawater.

An **evaporating basin** is used in a laboratory to evaporate the solvent from a solution. The basin is placed on a tripod stand over a Bunsen burner to heat the solution (Figure 10.5.3). Once the water is evaporated, the solute remains in the evaporating basin.



▲ FIGURE 10.5.2 A salt lake near Mt Eba in South Australia after the water has evaporated



▲ FIGURE 10.5.3 The equipment used to evaporate a solution in the laboratory

evaporating basin
a small porcelain dish used to evaporate solvent from a solution

crystallisation
the process in which excess solute in a solution forms crystals

Crystallisation

The solubility of a solution is measured by the amount of solute that can dissolve in a certain volume of solvent. Once the maximum amount of solute is dissolved, any additional solute will remain as an undissolved solid.

Crystallisation occurs when some of the solute comes out of solution and forms a solid because it cannot stay dissolved (Figure 10.5.4). This happens if the temperature of a solution is lowered, or the volume is reduced when water is removed. Once the crystals have formed, the liquid can be poured off, leaving crystals of the solute. Therefore, some of the solute has been separated from the solvent.



▲ FIGURE 10.5.4 Crystals of solute forming from a solution as it cools

Distillation

distillation

a process used to separate solutions that collect both the solute and the solvent

condenser

the piece of equipment in a distillation apparatus that cools the gas so that it changes to liquid

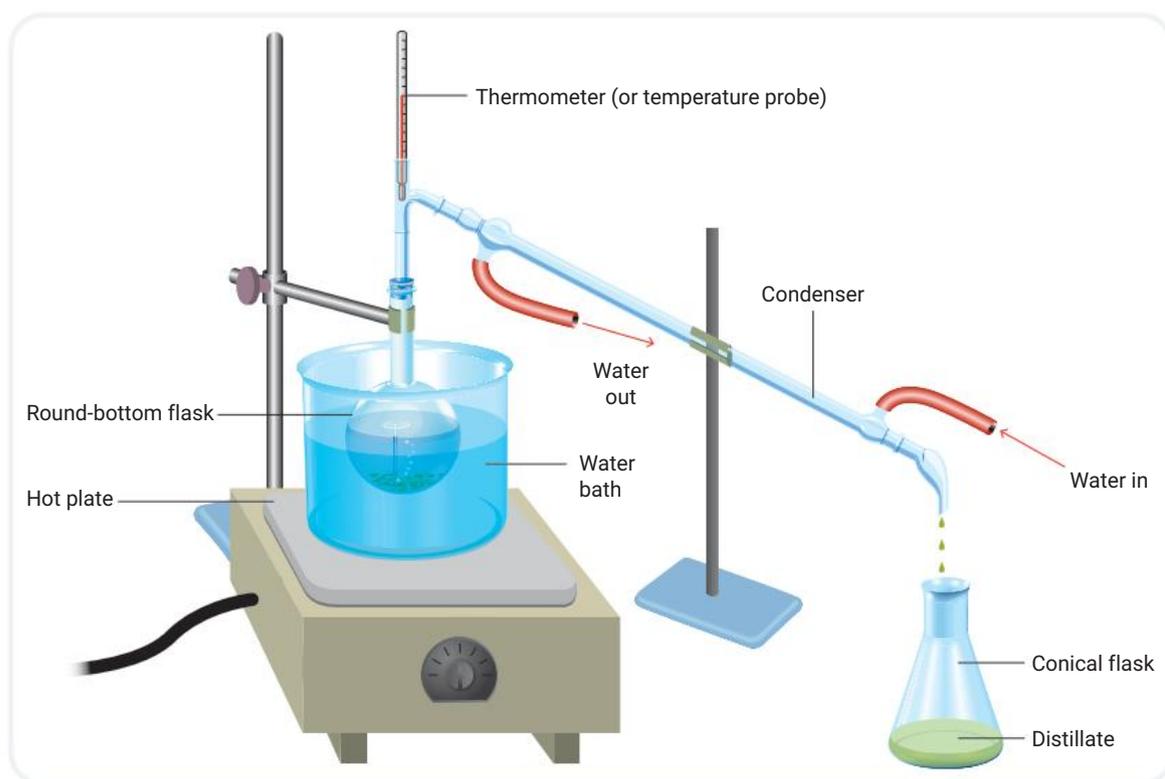
distillate

the liquid collected during the distillation process

Distillation is a process used to separate solutions when we want to keep both the solute and the solvent. The substances in the mixture need to have different boiling points so that they change state between liquid and gas at different temperatures.

The distillation apparatus (Figure 10.5.5) can separate a solution as it is heated. When a substance in the mixture reaches its boiling point, it forms a gas. The gas rises through a tube and passes into a **condenser**. The condenser has cold water running around its outside, which cools the gas so that it condenses, or forms a liquid. The liquid, called the **distillate**, collects at the end of the tube.

Distillation has many applications. Crude oil is a mixture of different compounds with different boiling points, including petrol, diesel and kerosene. Distillation separates the crude oil into its components. Distillation is also used to produce drinkable water from seawater.



▲ FIGURE 10.5.5 A distillation apparatus used in the laboratory

Making crystals

☆ ACTIVITY

10.5

⚠ Safety

Hot equipment can cause burns. Do not touch hot equipment. Use tongs or heatproof mitts. Use heatproof mats. Turn off the Bunsen burner after use, and allow all equipment to cool before attempting to move any part of the equipment.

Chemicals can cause damage if they are inhaled, are ingested or enter your eyes. Always wear safety glasses, lab coat and gloves. Do not inhale or ingest chemicals.

Broken glass can cut skin. Clean up any broken glass immediately and put it in the glass bin.

Before carrying out an experiment, remember that it is important to read through the instructions and listen to, or read, and follow the safety instructions given by your teacher.

Aim

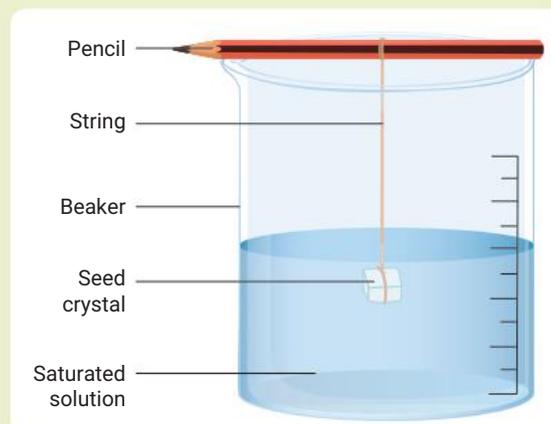
To obtain pure crystals from a solution

Material and equipment

- 10 g potassium aluminium sulfate (common alum) ($\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$)
- $\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$ seed crystal
- 70 mL distilled water
- electronic balance
- 100 mL measuring cylinder
- 2 × 250 mL beakers
- Bunsen burner
- tripod
- heatproof mat
- gauze mat
- stirring rod
- fine string
- pencil

Procedure

- 1 Weigh 10 g of alum and place it into a clean beaker.
- 2 Measure 70 mL of distilled water in a measuring cylinder.
- 3 Add the water to the beaker with the alum.
- 4 Set up the Bunsen burner, tripod and gauze mat on the heatproof mat.
- 5 Light the Bunsen burner and turn the flame to a blue flame.
- 6 Place the beaker on the gauze mat and gently heat the solution.
- 7 Use the stirring rod to stir the solution until all of the alum has dissolved.
- 8 Turn off the Bunsen burner and allow the beaker to cool enough to remove it from the tripod.
- 9 Tie the seed crystal onto the fine string and tie the string onto the pencil at a length so that the seed crystal will sit in the solution in the beaker.
- 10 Place the pencil on top of the beaker and suspend the seed crystal in the solution (Figure 10.5.6).



▲ FIGURE 10.5.6 Making crystals



- 11 Leave the beaker for approximately a week.
- 12 Each day, observe the beaker and record your observations.

Results

Record your daily observations in a table.

Analysis

- 1 Review your understanding of solutions using Module 9.5. Describe the type of solution that you made.
- 2 Which part of the solution were you able to obtain in a pure form?
- 3 Explain why the crystals formed from the solution.
- 4 Suggest a reason for using the seed crystal.

Conclusion

What conclusion can you make regarding the separation of a solution by crystallisation?

Extension

- 1 Predict what factors may affect the size of the crystal. Plan an investigation to test your prediction.
- 2 Describe a procedure for recovering as much of the solute as possible.

10.5 LEARNING CHECK

- 1 **Define:**
 - a distillate.
 - b condenser.
 - c evaporating basin.
- 2 What physical property is different between the parts of a mixture that are separated by distillation?
- 3 **Explain** why distillation has an advantage over evaporation for separating a solution.
- 4 **Describe** what you could do to stop crystallisation happening in a solution.
- 5 **Predict** which container would result in a liquid evaporating quicker: a test tube or an evaporating basin. Give a reason for your answer.
- 6 Fractional distillation is a special type of distillation. Conduct research to learn how fractional distillation works and what it is used for.
- 7 **Compare** distillate and filtrate – how are they similar and how are they different?

10.6 Other separation techniques: magnetic separation, flocculation and chromatography

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define magnetism, flocculation and chromatography
- ✓ explain how magnets, flocculation and chromatography separate mixtures.

GET THINKING

Look at the pictures in this module. What do you think they are showing? How do you think magnets, flocculation and chromatography separate mixtures? Annotate a diagram with your predictions. As you work through the module, add to or correct your annotations.

Magnetic separation

As you learned in Module 5.4, one physical property of matter is **magnetism**. This is the force experienced by metals such as iron, steel, nickel and cobalt. Most substances, such as aluminium, plastic, cardboard and wood, are not magnetic and so are not attracted to a magnet.

A **magnet** can remove magnetic substances from a mixture (Figure 10.6.1). One application of this separation technique is recycling. Recycling centres use powerful magnets to separate steel cans from aluminium cans. Scrap metal yards use large magnets to separate iron for recycling (Figure 10.6.2).

magnetism
a force that is experienced by metals such as iron



Quiz
Separation techniques

Interactive resource
Crossword: Separating substances

Extra science investigations
Does ink contain water?
Flocculation



Dorling Kindersley Ltd / Alamy Stock Photo

▲ **FIGURE 10.6.1** A magnet can separate iron nails from sawdust.



Petar An/Shutterstock.com

▲ **FIGURE 10.6.2** Magnetic separation in a scrap metal yard

Flocculation

flocculation

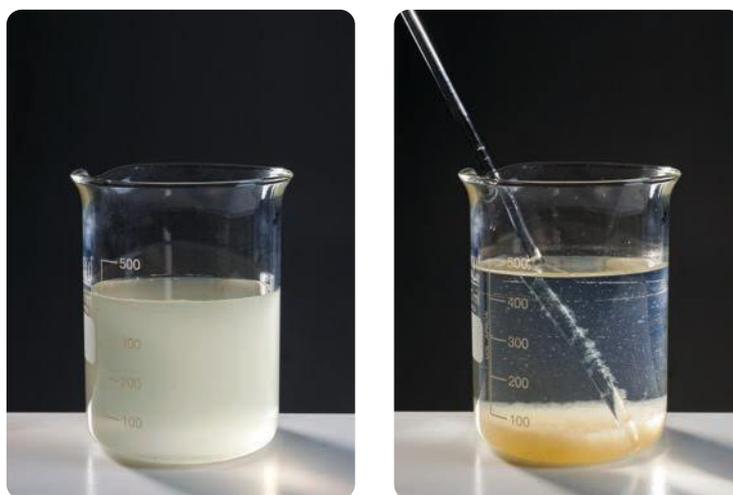
the process in which particles in a colloid join to form larger clumps

flocculant

a chemical added to a colloid to make the particles clump together

The particles in a colloid are so small that they are difficult to remove by methods such as filtration. **Flocculation** is a separation process that involves adding a chemical called a **flocculant** to the colloid (Figure 10.6.3). This chemical makes the colloid particles join to form larger clumps. The clumps settle and can then be removed by decanting, filtering or centrifuging.

Flocculation is commonly used to remove chemicals, micro-organisms and solids from water. It is used in swimming pools to remove fine particles so that the water becomes clear. Flocculants are also used to clean water to make it suitable to drink.



▲ FIGURE 10.6.3 A colloid before and after the addition of a flocculant

chromatography

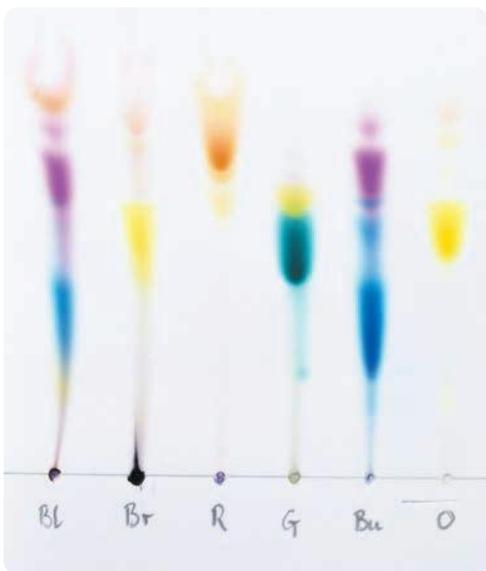
a process used to separate mixtures on the basis of their solubility

Chromatography

Chromatography literally means ‘colour writing’ and is used to separate mixtures on the basis of their solubility, mass, size and charge. There are many different types of chromatography, such as paper chromatography, thin-layer chromatography and gas chromatography. All types of chromatography use a mobile phase, or solvent, that moves over a stationary phase, which stays in the same place.

Paper chromatography can be used to separate different colours in mixtures, such as food colourings, pigments or dyes. The mixture is carried by a solvent (the mobile phase) along the paper (the stationary phase). Each part moves at a different speed depending on its solubility in the solvent. The more soluble it is, the faster it will travel. In this way, the parts of the mixture become separated from one another, as seen in Figure 10.6.4.

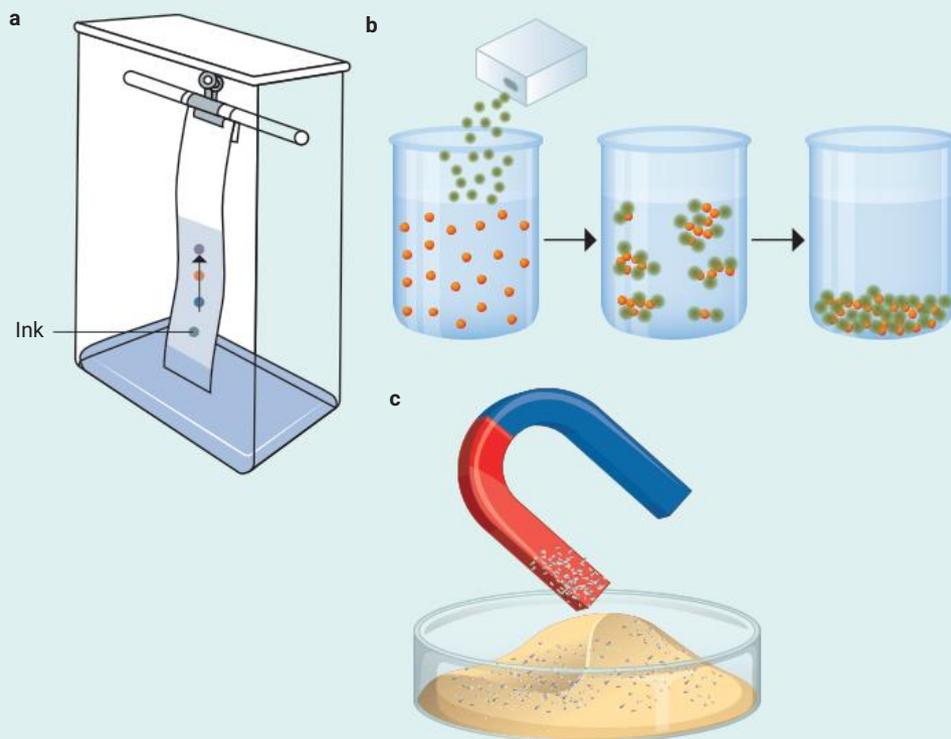
Other more sophisticated forms of chromatography are used in many areas of science. For example, forensic scientists use gas chromatography to test blood and urine samples for the presence of drugs or alcohol.



▲ FIGURE 10.6.4 Paper chromatography separating colours from different dyes. Note how different colours have separated at different places along the chromatography paper.

10.6 LEARNING CHECK

1 Name the type of separation technique used in the following diagrams.



2 Copy and complete the table.

	Magnetic separation	Flocculation	Chromatography
Physical property that differs			
Type of mixture that is separated			
Example			

3 Explain how flocculation is used to separate a colloid.

4 Chromatography is used in forensic science. For example, it is used to identify ink in documents.

a Describe how chromatography could be used to identify the ink.

b Discuss whether this should be the only evidence used to convict a suspect.

5 One method of treating water so that it is safe to drink is flocculation. Using this method, the solid settles, as shown in Figure 10.6.3.

a Describe a method you could use to separate the solid from the clean water.

b Draw a diagram of the apparatus you would use to perform this separation.



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THIS SKILL:

- ▶ separating a mixture using chromatography.

USING CHROMATOGRAPHY TO SEPARATE A MIXTURE

AIM

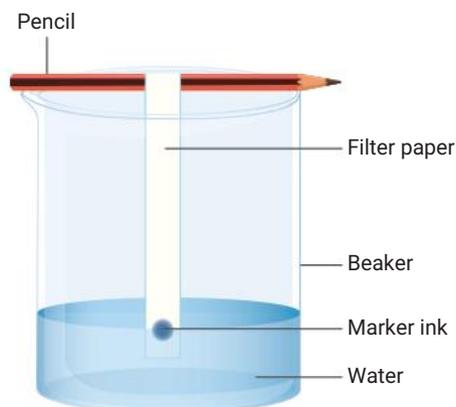
To use chromatography to separate the components of marker pens

MATERIALS AND EQUIPMENT

- 250 mL beaker
- pencil
- filter paper
- sticky tape
- a range of water-soluble marker pens in different colours

PROCEDURE

- 1 Take a piece of filter paper and cut it into strips approximately 10 cm long by 1–2 cm wide.
- 2 Use sticky tape to attach one end of a paper strip to a pencil, as shown in Figure 10.7.1.



▲ FIGURE 10.7.1 Chromatography experiment set-up

- 3 Use a water-soluble marker to draw a large dot about 1 cm above the other end of the paper strip.
- 4 Add water to a 250 mL beaker so that the water is about 0.5 cm deep.
- 5 Suspend the strip of filter paper so the end of the paper dips into the water, as shown in Figure 10.7.1.
- 6 Leave the set-up for a few minutes or until the water has moved at least three-quarters of the way up the paper strip.
- 7 Repeat steps 2–6 with different coloured marker pens.

RESULTS

- 1 Select the marker that separated the best and sketch the result into your book.
- 2 Did all the markers show separation? Rank your markers in order of most separation to least separation.

ANALYSIS

- 1 Explain why the marker ink separated.
- 2 Compare the colour of the original ink to the final colours. Are the final colours what you would expect? Why or why not?
- 3 Challenge: If you repeated this experiment with permanent marker, the ink would not separate. Do some research to investigate what you could use instead of water to separate permanent marker ink.

CONCLUSION

Write a conclusion outlining what happened in your investigation.



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ identifying problem-solving strategies and proposing solutions to separate a mixture
- ▶ designing a procedure for separating two substances using a range of separation techniques.

Scientists are often faced with problems they have to solve. It is the job of a scientist to use their knowledge and skills to propose a solution, test the solution and apply the solution, hopefully to fix the problem.

As a scientist, you have a bank of knowledge and skills you can use to solve a problem. You learned about some of these problem-solving strategies in Chapter 1. In this chapter, you have explored some different separation techniques and performed experiments to practise these skills. In this investigation, you will need to decide which of these techniques is most appropriate. You will then design a procedure to collect both substances after you separate them.

You could try:

- reviewing the physical properties and applying techniques relating to them to the substances in this experiment
- reviewing the separation techniques and identifying those that may be applicable
- having individual and group brainstorms and discussions to propose an idea.



Video

Science skills
in a minute:
Problem solving
in science

Science skills resource

Science skills
in practice:
Problem solving

SEPARATING A MIXTURE

AIM

To separate a mixture

MATERIALS AND EQUIPMENT

- ☑ mixture supplied by your teacher consisting of solid calcium carbonate (insoluble) and solid copper sulfate (soluble). Your teacher will know exactly how much of each chemical is in the mixture
- ☑ 250 mL beaker
- ☑ stirring rod
- ☑ distilled water
- ☑ equipment for a range of separation techniques, e.g. filter paper, filter funnel, conical flask, Bunsen burner, evaporating basin

Safety

Hot equipment can cause burns. Do not touch hot equipment. Use heatproof mitts, tongs and heatproof mats.

Chemicals can cause damage if they are inhaled, are ingested or enter your eyes. Always wear safety glasses, lab coat and gloves. Do not inhale or ingest chemicals.

PROCEDURE

- 1 Work in groups of two or three to develop a plan for separating the mixture.
- 2 Write a procedure or draw a flow chart showing your planned steps.
- 3 Show your procedure to your teacher.
- 4 Use your procedure to separate your mixture. You may need a couple of days to complete this.
- 5 Take photos of the steps that you used. Add annotations to label key equipment. If you cannot take photos, draw a scientific diagram with pencil and ruled lines.
- 6 Make a note of any changes to your procedures or any details that you missed.
- 7 Use an electronic balance to measure the mass of each part of the mixture. Record this in your results table (shown below).
- 8 Ask your teacher how much of each chemical was originally added.

RESULTS

Copy and complete the results table shown below.

ANALYSIS

- 1 Use your procedure, photos and notes about any changes to write a detailed method of what you did to separate the mixture.
- 2 For each technique you used, write a paragraph explaining its relevance. Include the physical property that it related to and what happened to each part of the mixture.
- 3 Compare the masses that you collected with the masses that your teacher originally added. Suggest a reason for any differences.

CONCLUSION

Write a short paragraph summarising how your method separated the mixture.

Part of the mixture collected	Mass collected after separation (g)	Mass originally added to the solution (g)
Calcium carbonate		
Copper sulfate		

**IN THIS MODULE
YOU WILL:**

- ✓ examine Aboriginal and Torres Strait Islander Peoples' use of different separating techniques.

Separation techniques

For many thousands of years, Aboriginal and Torres Strait Islander Peoples have selected, processed and used natural material for many purposes, including cooking and medicine. They have applied a variety of separation techniques to separate out the parts of a mixture that are useful or the parts of a mixture that are harmful. This has allowed Aboriginal and Torres Strait Islander Peoples to obtain food and clean drinking water and develop medicines. These separation techniques include hand-picking, winnowing, yandying, sieving, filtering, straining, cold-pressing and steam distillation. Many of these techniques are still in use today.

To successfully perform these separation techniques prior to colonisation, Aboriginal and Torres Strait Islander Peoples developed a complex understanding of what made up the mixtures available in their Country/Place. They understood the physical properties of the mixtures, such as their hardness, density, boiling point and solubility. They also understood the most effective techniques for each mixture's separation.

Separating to obtain food

A combination of different separation techniques is used to obtain seeds for cooking and eating. For example, the Alyawarre Peoples of the Sandover River region in the Northern Territory harvested about 36 different seed types for food. After collecting the seed pods, they beat them with sticks (a process known as threshing) to break the pods and release the seeds. A mixture containing seeds, broken pods, sticks and dirt was then scooped up from the ground using a specially made wooden bowl, called an arlengarr. Different Aboriginal and Torres Strait Islander cultural groups had a specific name and, at times, design for these wooden dishes. Since colonisation, the term coolamon has been applied to containers of the type seen in Figure 10.9.1.

Large pieces of unwanted material are also removed from the mixture in the coolamon by hand-picking. The remaining mixture is then winnowed (Figure 10.9.2). In this process, the mixture is thrown in the air to allow the lighter particles to be blown away and the heavier particles, such as seeds, to be caught in the coolamon. This process must be repeated many times to remove all the lighter particles and leave behind only the seeds.



▲ **FIGURE 10.9.1** An example of a coolamon, origin unknown



▲ **FIGURE 10.9.2** Winnowing to separate a mixture of seeds



▲ **FIGURE 10.9.3** A bicornate-shaped basket, known as jawun, used by the rainforest peoples of north-eastern Queensland to strain, sieve and filter mixtures



▲ **FIGURE 10.9.4** The Gunditjmara Peoples used banksia cones to filter drinking water.

Yandying, like winnowing, is used to separate components of a mixture with different densities, such as seeds and sand. This process is similar to how people pan for gold. In this process, the mixture is placed in a wooden container. One corner of the container is raised, and the container is gently shaken back and forth, causing denser particles to move to the bottom while less dense particles remain at the top.

Mulga seeds were an important food source for the Yankunytjatjara Peoples of north-west South Australia. Before mulga seeds could be consumed, they had to undergo two yandying processes. The collected seed pods would first be threshed and rubbed to release the seeds. The resulting mixture was then yandied to separate the seeds from any remaining pod pieces. The clean seeds were then baked in hot sand and ashes. The mixture of seed, sand and ashes was then winnowed and yandied to again separate the seeds.

Special woven bicornate-shaped ('bicornate' means two-horned) baskets made by the Bama Peoples of tropical north Queensland have long been used as sieves, strainers or filters. The Dyirbal People call them jawun (shown in Figure 10.9.3). Baskets may be loosely woven with larger holes for washing away sand and dirt from food or straining water from food. Baskets may also be tightly woven with small holes. These were used to strain water for drinking. They could also be filled with foods that needed to have toxins removed before eating, such as the cooked, thinly sliced seeds of a cycad, which were then placed in running water to leach away toxins.

Separating to obtain clean water

Sand and various types of plant parts were also used to filter water for drinking. For example, in traditional times the Gunditjmara Peoples of south-west Victoria used flowering honeysuckle (banksia) cones to filter dirty water for drinking. The cone would be used like a straw. Sucking water through the cone would exclude impurities so that the water would be clean enough to drink.

Aboriginal and Torres Strait Islander Peoples developed effective filters from the stems and hollow stalks of many different plants, such as the lotus lily, bamboo, bulrush and swamp panic grass. These were used as drinking straws to screen out impurities and provide clean water for drinking.

☆ **ACTIVITY 1**

- Design** a method to separate rice from a mixture containing leaves, rice, grass clippings and sand.
 - List** the steps needed to separate each component. **Name** the separation technique used in each step.
 - For each step **identify** the properties used to achieve the separation of each specific component.
- Explain** what properties are used to remove toxins from food by leaching.
- Propose** how the traditional knowledge of Aboriginal and Torres Strait Islander Peoples of using plants for drinking straws could be applied to reduce the environmental impact associated with the use of plastic drinking straws.

Separating to obtain medicines

For thousands of years, Aboriginal and Torres Strait Islander Peoples have understood, extracted and used the medicinal components of native plants. Traditionally, a variety of plant oils would be extracted by steam distillation. By placing fresh, wet plant matter over cool fires, steam was used to release the medicinal oils in the leaves which could then be inhaled. For example, the Bundjalung Peoples of northern New South Wales inhaled vapours from the heated leaves of tea tree to effectively treat the symptoms of coughs and colds.

The medicinal component of plant material can be obtained by boiling or soaking the plant material in hot or cold water, resulting in a solution that contains the desired component. This mixture can then be drunk or applied to wounds. For example, the oil from eucalyptus leaves was widely used by many Aboriginal Peoples in steaming, in a drink and as a wash to treat wounds. The Pitjantjatjara Peoples of north-west South Australia make a drink to relieve sore throats by soaking the foliage of the flat sedge plant in hot water.

Cold-pressing is another traditional technique used to extract medicinal components from plant material. One advantage of this technique is that no heating is required. To cold-press, the plant material is ground to a pulp and then pressed to obtain oils, which can be applied externally.



Joe Sambono

▲ **FIGURE 10.9.5** Tea tree leaves and flowers

☆ **ACTIVITY 2**

- Identify** three separation techniques used to obtain medicines.
 - For each technique identified, **explain** what properties are used in the separation process.
- Discuss** an example of where one of these techniques and medicines is used today.

10.10

Separation techniques
used in recycling

BY THE END OF
THIS MODULE, YOU
WILL BE ABLE TO:

- ✓ explain how separation techniques are used in recycling.

Narelle Koppers, Founder, Precious
Plastic Margaret River



▲ FIGURE 10.10.1 A plant pot made from recycled plastic lids

People are becoming more aware of the importance of recycling. During recycling, the materials are broken down into their raw materials and then made into new products. For example, one company, Precious Plastic in Margaret River, Western Australia, melts plastic lids and then creates products such as plant pots (Figure 10.10.1).

Different methods of recycling are used for different materials. Therefore, the items must be separated according to what they are made from. You can start this at home by:

- separating plastic bottles, glass bottles and aluminium cans from general waste and placing them into the recycling bin
- taking scrap metal to a scrap metal yard
- taking batteries, light globes, soft plastics and mobile phones to recycling centres
- using green waste (plant material) to make compost
- putting paper recyclable materials into the recycling bin.



Video activity
How recycling works

The materials in your recycling bin are separated at the recycling centre.

The following steps are involved in separating the wastes.

- 1 The waste passes over a turning cylinder with holes. Heavy items, such as plastic, glass and metal, fall through, leaving paper and cardboard.
- 2 Workers remove cardboard from paper as it moves past them on a conveyor belt.
- 3 The heavy items move along a separate conveyor belt. As they pass under a magnet, the steel cans are attracted to it and lifted away from the other materials.
- 4 Workers manually separate milk bottles, aluminium cans and plastic bottles as they move along a conveyor belt.



▲ FIGURE 10.10.2 A magnet separates the steel from other recyclable materials.

10.10 LEARNING CHECK

- 1 **List** three physical properties used in the separation of recyclable materials.
- 2 A turning cylinder separates the heavy products from the lighter products. **Name** the separation technique utilised in this step.
- 3 **Explain** why manual sorting is needed to separate paper and cardboard.
- 4 A new technology for separating plastics uses invisible barcodes that allow a scanner to identify the type of plastic and whether it can be recycled. **Discuss** the value of this technology, identifying an advantage and a disadvantage of adding the barcode to products.

10 REVIEW

REMEMBERING

1 Match each piece of equipment (a–g) with its use (i–vii).

Equipment	Use
a Condenser	i Separates a solid sediment from water very quickly by spinning
b Centrifuge	ii Separates substances according to the size of the particles
c Filter paper	iii Cools vapours and turns them back into a liquid
d Evaporating basin	iv Separates solutions into their parts by boiling
e Magnet	v Holds filter paper during filtration
f Distillation apparatus	vi Separates iron, cobalt and nickel from other substances
g Funnel	vii Evaporates water from a solution while it is gently heated

2 State whether each of the following separation techniques is used to separate a suspension, colloid or solution.

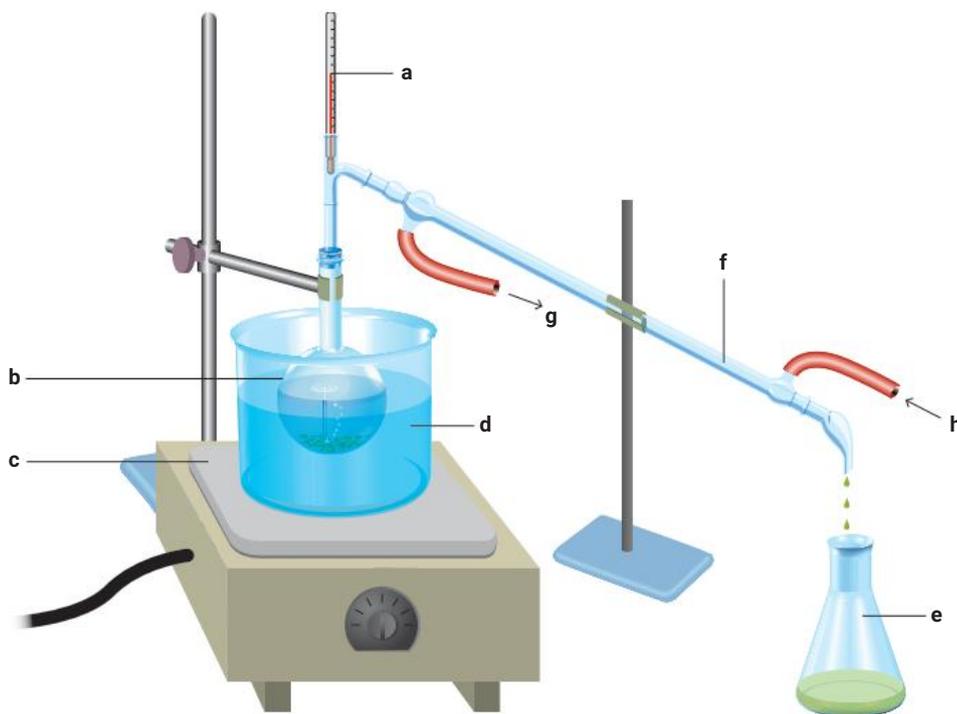
- a Distillation
- b Flocculation
- c Centrifuging
- d Crystallisation

3 State the name given to the substance:

- a left in the filter paper.
- b collected at the end of distillation.
- c that passes through a filter.
- d added to a colloid to make the particles clump together.

4 Draw a labelled scientific diagram of the equipment you would use in the laboratory to recover the salt from a salt solution.

5 Name the parts (a–h) of the distillation equipment in the following diagram.



6 Describe the function of the following parts of distillation equipment.

- a** Thermometer
- b** Condenser
- c** Hot plate or Bunsen burner

UNDERSTANDING

7 Explain why distillation is used instead of evaporation to separate some solutions.

8 Identify which technique(s) could be used to:

- a** collect salt from seawater.
- b** determine the colours in black jelly beans.
- c** remove large pebbles from a mixture of soil, leaves and dirt.
- d** collect drinking water from seawater.
- e** determine if an Olympic sprinter has any illegal chemicals in their blood.

9 List the methods of decanting, filtration and sedimentation in order from most to least effective for separating a suspension of sandy water. **Explain** your answer.

10 State whether the following statements are true or false. For those that are false, rewrite them so that they are true.

- a** Only solutions can evaporate.
- b** If a salt solution is left on the windowsill for long enough, the solute will evaporate, leaving the solvent behind.
- c** Increasing the temperature of a solution will increase the solubility of the solute in the solvent.
- d** Crystallisation can occur only by cooling a saturated solution.

11 Describe the similarities and differences between the processes of evaporation and crystallisation.

12 Explain how flocculation can make the water in a spa clear.

13 Explain how distillation is similar to water evaporating from the ocean and then falling as rain.

APPLYING

14 Aboriginal Peoples use yandying and winnowing to separate mixtures. **Compare** these two techniques, **identifying** the circumstances when each is used.

15 Describe how sedimentation and decantation are used in the kitchen to separate peas from the water they were cooked in.

16 Compare the filter paper used in the laboratory with a strainer used in the kitchen.

17 Baleen whales are called filter feeders because they take huge amounts of water into their mouths to separate out fish and krill for food, and expel the water. **Suggest** what the structure of a baleen whale's mouth looks like. **Explain** your answer.

18 The Dead Sea receives very little rainfall. The air is dry and temperatures are always high. Use this information, and your understanding of saturated solutions, to **explain** why the Dead Sea coastline is covered in solid salt.

19 When using chromatography to separate a mixture, only small amounts of the mixture are required. Why would this be helpful if gas chromatography was used to determine the percentage of alcohol in a blood sample?

20 In dairies, fresh milk is separated into cream and milk. Originally this was done by leaving the fresh milk until the cream rose to form a layer on top that could be skimmed off. In 1894, Gustaf de Laval patented the first milk separator. The fresh milk was placed in the separator. When the handle was turned, the separator bowl would spin at thousands of revolutions per second.

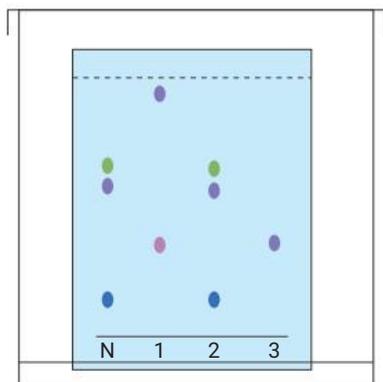
- a** What type of mixture is fresh milk?
- b** **Outline** the properties of the cream and milk that are used in each of these separation techniques.
- c** What type of separation technique was used initially? **Describe** this process.
- d** What type of separation technique was used by the milk separator? **Explain** how this was able to separate the cream from the milk.

21 You are camping in the outback, and have run out of water. The water in the nearby waterhole looks rather murky but you have seen animals drinking it. Using anything you brought along with you, what steps would you take to clean this water so that it is likely to be safe to drink? You can use drawings to explain what you will do.

22 What are some methods that you have used at home without realising they were physical separation techniques?

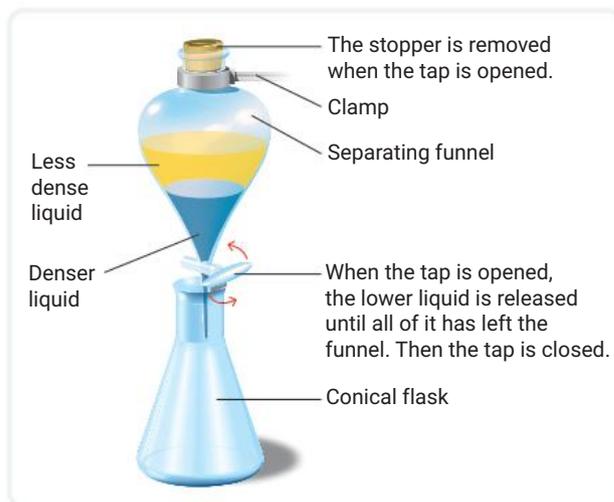
EVALUATING

- 23** A mixture of sand, salt and water to be separated in the laboratory weighed 235.6 g. After the mixture was filtered, the residue was wet and the filtrate weighed 202.9 g. The filtrate was then distilled until 4.03 g of white powder was left in the flask.
- Identify** the residue, filtrate and distillate.
 - From the data given, **determine** the mass in the original mixture of the:
 - sand.
 - salt.
 - water.
 - After filtration, the residue was still wet. **Assess** the accuracy of the masses obtained from this activity.
 - How could this experiment be done in a different way to improve the accuracy of the mass measurements of the sand, salt and water? Use a flow chart to show your modified method.
- 24** There was a break-in at a jewellery store. In the store, there is a note written in black ink. Police question three people: person 1, the store owner (who came from home after being notified); person 2, a young woman (who reported hearing the alarm and notified police); and person 3, a local security guard. Each person had a different black ink pen. Forensic scientists use chromatography to compare the ink in each person's pen with the ink on the note. The results are shown below.



- Whose pen was used to write the note? **Explain** how you determined this.
- Does this mean that person was the thief? Give reasons for your answer.

- 25** In 2010, two students from Rice University in Texas, United States, created a cheap centrifuge that could be used to separate blood without using electricity. They made their centrifuge from a salad spinner at a cost of about \$30.
- What features of a salad spinner would make it suitable for separating blood?
 - What modifications would be needed, and why?
 - What impact could this invention have in underdeveloped countries?
- 26** Another separation technique uses a separating funnel, as shown in the diagram below.
- Use the information provided and your knowledge of physical properties to **explain** how a separating funnel separates a mixture of oil and water.



CREATING

- 27 Create** a concept map to organise the information you have learned about the different separation techniques.
- 28** Salt is only slightly soluble in a liquid called ethanol. Ethanol has a boiling point of approximately 78°C. **Write** a detailed method you could use in the laboratory to separate a mixture of sand, gravel, ethanol and salt. The sand, gravel and salt must be reclaimed as solids, and you must also reclaim the liquid ethanol. **Explain** how each separation process allows the collection of each substance.

SCIENCE IN DEPTH STUDY

#10

1 Connect what you've learned

In this chapter, you've learned about different separation techniques. Identify which of these techniques might be useful in purifying water to be used for drinking and household use. Justify each choice you make.

2 Check your thinking

Do some research into how water is purified in New South Wales. Which techniques that you identified in part 1 are actually used?

3 Get into action

You are presented with a sample of water that has been polluted to model what happens in dams. The water contains dirt and rocks, salt, leaves and twigs and clay (which forms a suspension in water). Plan how you might purify this water to eliminate all the pollutants.

4 Communicate

Present your purification method to your classmates and teacher in the form of a flow chart, showing the techniques used at each step.



LIVING SYSTEMS

SYLLABUS OUTCOMES

A STUDENT:

- ▶ describes the role, structure and function of a range of living systems and their components SC4-LIV-01
- ▶ identifies questions and makes predictions to guide scientific investigations SC4-WS-02
- ▶ uses a variety of ways to process and represent data SC4-WS-05
- ▶ communicates scientific concepts and ideas using a range of communication forms SC4-WS-08

CHAPTERS RELATED TO THIS FOCUS AREA ARE:

- ▶ **CHAPTER 11** – ANIMAL SYSTEMS
- ▶ **CHAPTER 12** – PLANT SYSTEMS
- ▶ **CHAPTER 13** – ECOSYSTEMS

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11

Animal systems

11.1 Body organisation (p. 390)

Cells, tissues and organs form systems that work together to make the functioning organism.

11.2 Digestive system (p. 392)

The digestive system breaks down food for absorption into the body.

11.4 Respiratory system (p. 398)

The respiratory system takes up oxygen from the air, moves it into the blood and removes carbon dioxide from the body.

11.3 WORKING SCIENTIFICALLY: Modelling systems (p. 397)

The structure and function of the mouth

11.5 WORKING SCIENTIFICALLY: Writing a discussion (p. 400)

Does exercise affect your ability to hold your breath?

11.6 Circulatory system (p. 402)

The circulatory system transports nutrients and waste to and from every cell in the body through the blood.

11.8 WORKING SCIENTIFICALLY: Assessing scientific models (p. 408)

Modelling kidney function

11.7 Excretory system (p. 406)

The excretory system removes toxic waste from the body.

11.9 Disorders of body systems (p. 411)

Disorders of body systems cause predictable symptoms that may be successfully diagnosed and treated.

11.10 ABORIGINAL AND TORRES STRAIT ISLANDER SCIENCE CONTEXTS: Knowledge of body systems (p. 413)

Aboriginal and Torres Strait Islander Peoples have an in-depth understanding of the internal systems of animals.

11.11 SCIENCE IN CONTEXT: Scientists as communicators (p. 415)

Scientist Jane Goodall, an expert in chimpanzees, is a well-known science communicator.



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▲ FIGURE 11.0.1 The creation of artificial organs is an important research area, because there is a lack of organs from donors.

Surgeons began doing human organ transplants around 1954. The first transplanted organ was a kidney. Since then, surgeons have successfully transplanted livers, lungs, hearts and pancreases in patients. Currently, there is a system that matches donated organs to people who need an organ transplant. In Australia, there are around 1800 patients on waiting lists to receive an organ. Sadly, many of them won't receive an organ because of the lack of donors. As a result, many research organisations are studying how to create reliable artificial organs that could be used in place of organs from donors.

- ▶ What research is needed to create an artificial organ?
- ▶ How can an artificial organ be created?
- ▶ What technology and conditions are needed for a successful artificial organ transplant?

#11 DIVE INTO SCIENCE!

At the end of this chapter, you can complete Science in Depth Study #11. You can use the information you learn in this chapter to complete the project.

Assessments

- Prior knowledge quiz
- Chapter review questions
- End-of-chapter test
- Depth study: Research project

Videos

- Science skills in a minute: Writing a discussion (11.5); Assessing models (11.8)
- Video activities: The large intestine (11.2); How does COVID affect the lungs? (11.4); The heart (11.6); The kidneys (11.7); Heart disease (11.9)

Science skills resources

- Science skills in practice: Discussions in science reports (11.5); Assessing scientific models (11.8)
- Extra science investigations: Lung capacity (11.4); Heart dissection (11.6); Kidney dissection (11.7)

Interactive resources

- Crossword: The heart (11.6)
- Label: Parts of the digestive system (11.2)
- Drag and drop: Chemical groups in food (11.2)
- Quiz: Levels of organisation (11.1)

11.1 Body organisation

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe the relationship between cells, tissues, organs, systems and organisms
- ✓ explain why multicellular organisms have multiple systems that work together.



Quiz
Levels of
organisation

GET THINKING

Think about the organisation in your school. There are many people doing different jobs but they all work together to keep the school running efficiently. How does this compare with the organisation and relationships of the body systems of living things?

From simplest to most complex

hierarchical

an order of importance

tissue

a collection of cells that have similar structures and functions

organ

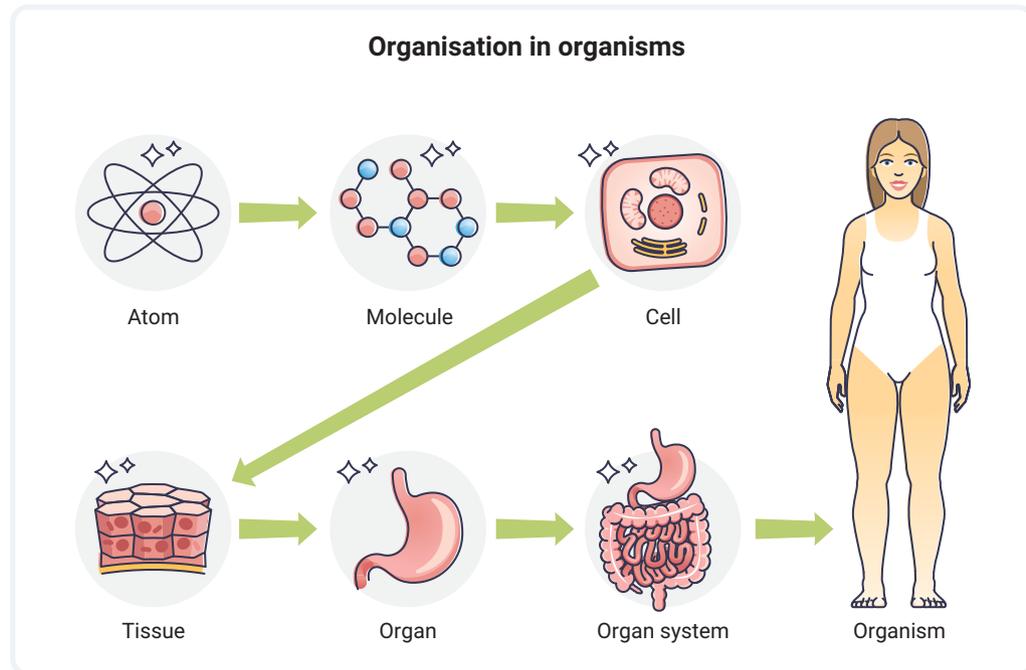
a collection of different tissues that combine to perform a specific function

system

a group of organs that work together to perform a specific function

In Chapter 7 you learned about how cells, tissues, organs and systems in the human body are organised from the simplest parts to the most complex. We call this a **hierarchical** organisation (Figure 11.1.1). Cells are the basic unit of living things, but as you learned in Chapter 8, all matter consists of smaller units called atoms.

The hierarchical organisation of the body allows us to learn and understand how an organism works. It is a model that explains how the body's cells, **tissues**, **organs** and **systems** are interconnected. It shows us how these different levels work together to keep an organism functioning so it can interact with its environment, survive and reproduce.



▲ FIGURE 11.1.1 Hierarchical organisation in organisms, from the atomic level to the organ systems that are part of a whole organism

Body systems working together

Imagine you are at the gym training for the swimming competition at the school carnival. As you run on the treadmill, your body will start to need more oxygen to go to your muscles. The red blood cells passing through your lungs carry the oxygen that you breathe in. To make more oxygen available, your heart rate will increase to pump those red blood cells more often to the muscles. After some time, you feel thirsty because your kidneys send a signal to your brain telling you to drink water and keep your body hydrated. As this example shows, no organ or system in the body is isolated from the others, as they work and interact together to let you train efficiently (Figure 11.1.2).



▲ FIGURE 11.1.2 The interactions between cells (red blood cells), tissues (muscles), organs (heart, lungs, kidneys) and systems (respiratory, circulatory, excretory and musculoskeletal) during exercise

11.1 LEARNING CHECK

- 1 Describe** what a hierarchal organisation means in terms of an organism.
- 2 Create** a flow chart that represents the hierarchical organisation in organism from cells to systems, using an organ system of your choice.
- 3 Choose** an activity that you do often during the day. **Relate** all the organs and systems that help you to perform that activity.
- 4 Evaluate** how the activity you chose in question 3 would be affected if one of the body's organs failed.

11.2 Digestive system

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ explain how the structures of cells and organs relate to their functions in the digestive system
- ✓ compare and contrast the digestive system in a human with the digestive systems of other animals with different diets.



Video activity
The large intestine

Interactive resources

Label: Parts of the digestive system

Drag and drop:
Chemical groups
in food

GET THINKING

Does it surprise you that the food you eat takes more than 24 hours to pass through your digestive system? In this module you will find out why it takes so long.

Digestive processing

The foods we eat are made up of three main chemical groups: **carbohydrates**, **proteins** and **fats** (Figure 11.2.1). These substances are complex. The body cannot use food in this complex form. The role of the digestive system is to break down these foods into simpler, more useful substances, as shown in Table 11.2.1.

▼ TABLE 11.2.1 Complex forms of substances and the simpler forms they are broken down to by the digestive system

Complex form of substance	Simple form of substance	What foods is this found in?
Carbohydrates	Simple sugars, such as glucose	Pasta, rice, bread, potatoes
Protein	Amino acids	Meat, cheese, fish, soybeans
Fats and lipids	Fatty acids and glycerol	Butter, oils

carbohydrates

a complex food group found in starchy foods such as bread and rice

proteins

a complex food group found in foods such as meat, fish, soybeans and cheese

fats

a complex food group found in foods such as butter and cream

mechanical digestion

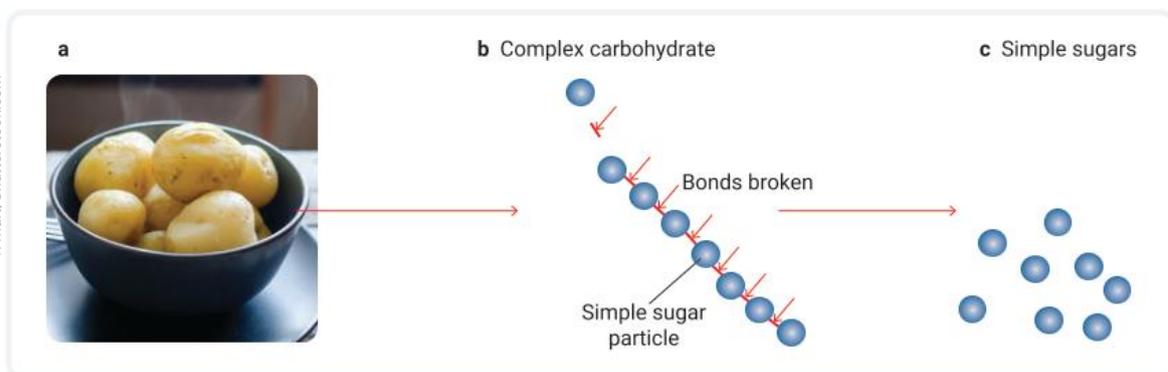
the physical breakdown of food into smaller pieces

chemical digestion

the chemical breakdown of complex compounds into simpler compounds

The breakdown of food can be classified as either chemical or mechanical digestion.

Mechanical digestion (physical digestion) is when large pieces of food are broken down into smaller pieces of food. This increases the surface area of food so it can be acted on by enzymes in chemical digestion. **Chemical digestion** occurs when enzymes break down complex compounds into simpler compounds.



▲ FIGURE 11.2.1 (a) Our teeth cut cooked potato into smaller pieces. (b) Enzymes start to break down the complex carbohydrates in the potato. (c) Simple sugar particles are released.

Mouth

The mouth is the structure into which food is **ingested**. It contains the teeth, the tongue and salivary glands – all essential for the initial digestion of food. The teeth break food into small pieces in the process of mechanical digestion.

When you are eating, you may have noticed that the food becomes slippery. This is due to saliva, made by the cells of the salivary glands, lubricating the food so it moves easily down the throat. Saliva also contains the **enzyme amylase**, which starts the chemical digestion of the carbohydrate **starch** into simple sugars. Your tongue then moves the ball of food (**bolus**) to the back of the mouth to the entry of the oesophagus.

ingested

taken in; eaten

amylase

the enzyme that digests carbohydrates

starch

a complex carbohydrate found in potatoes and other plants; also a form of glucose storage in plants

bolus

a ball of food that passes into the oesophagus from the mouth

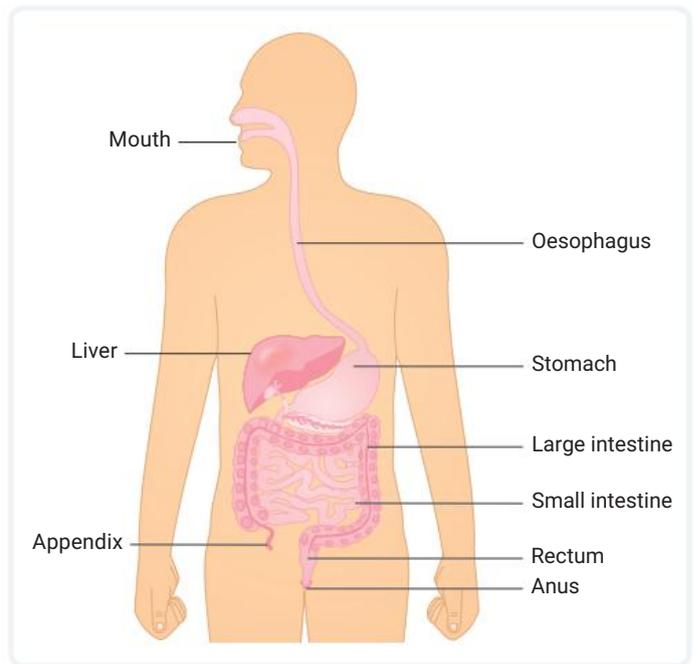
The oesophagus

The oesophagus (Figure 11.2.2) is a long, muscular tube that transfers food from the mouth to the stomach. The circular muscles in the oesophagus contract and relax in waves so that food is pushed along. This is known as **peristalsis**. At the end of the oesophagus is a special ring-like muscle, or **sphincter**, that opens and closes the entrance to the stomach. This sphincter prevents the acidic contents of the stomach from flowing back up into the oesophagus and irritating the oesophagus wall – a condition known as **heartburn**.

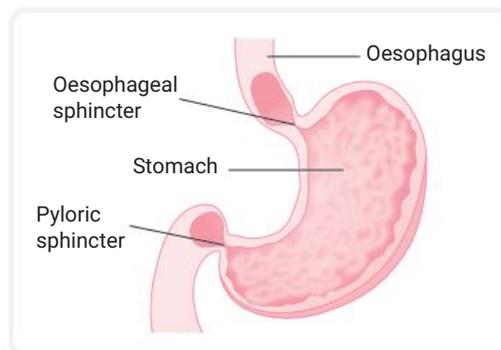
The stomach

The stomach (Figure 11.2.3) is a muscular sac at the end of the oesophagus. Its wall contains many folds that allow it to expand to hold up to 3 litres after a large meal. This is 60 times its usual volume.

The stomach wall contains glands that secrete protein-digesting enzymes and **hydrochloric acid** that make the stomach very acidic. The mixture of food, acid and enzymes formed in the stomach is called **chyme**. The muscular wall of the stomach contracts to mix and churn the chyme, another example of mechanical digestion.



▲ FIGURE 11.2.2 The organs of the digestive system



▲ FIGURE 11.2.3 A cutaway section of the stomach, showing its sphincters

peristalsis

a progressive wave of contraction and relaxation along the digestive tract

sphincter

a ring of muscle that can close off a tube

heartburn

a burning feeling in the oesophagus caused by rising stomach acid

hydrochloric acid

a type of acid; in the stomach it helps to digest food

chyme

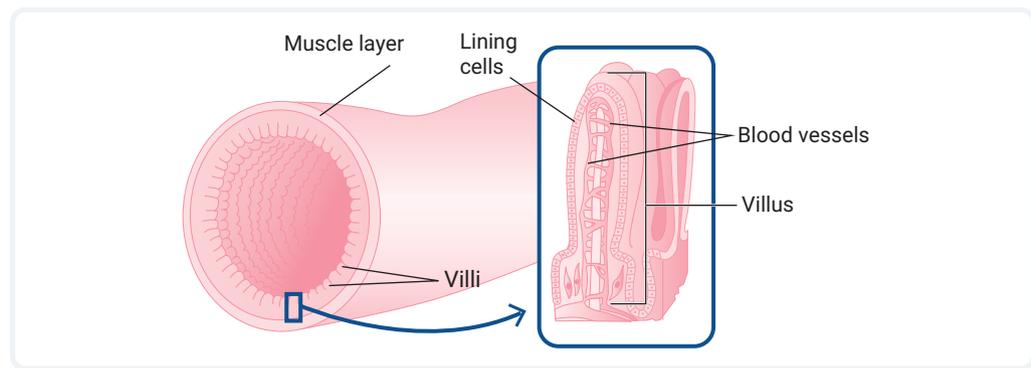
partially digested food that passes from the stomach to the small intestine

The small intestine

Chyme is released in small amounts from the stomach into the small intestine through another sphincter. Laid out straight, the small intestine would stretch to more than 6 metres. Peristalsis continues in the small intestine. This helps to mix the chyme with enzymes that digest protein, fat and carbohydrates.

Magnification of the wall of the small intestine (Figure 11.2.4) shows that it is made up of **villi** (singular: villus). These finger-like extensions increase the surface area of the small intestine and take blood vessels close to the chyme. This arrangement ensures that the products of digestion, including amino acids, fatty acids and glucose, are rapidly absorbed into the blood along with large amounts of water. Any material that has not yet been absorbed remains in the small intestine and continues along the digestive tract to the large intestine.

villi
small finger-like projections on the walls of the small intestine that increase surface area



▲ FIGURE 11.2.4 A magnified view of the wall of the small intestine lined with villi, which increase the surface area that is available for absorption of nutrients

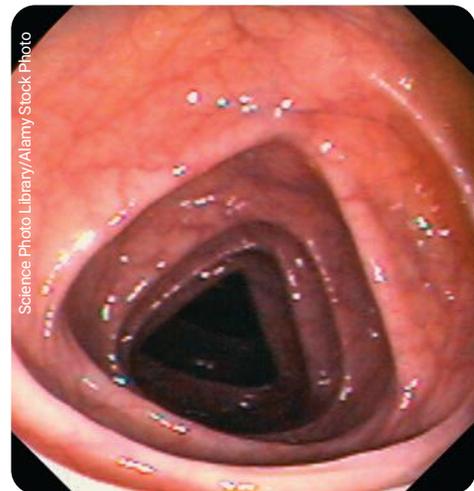
The large intestine

The small intestine attaches to the large intestine near the **appendix**. At only 1.5 metres long, the large intestine is named for its width rather than its length. The main function of the large intestine is to absorb water, vitamins and minerals into the capillaries of the circulatory system (Figure 11.2.5).

The cellulose cell walls of plants cannot be broken down by the human digestive system. This is commonly referred to as **fibre**, or 'roughage', in the diet and is beneficial in two ways. Fibre gives bulk to the intestinal contents and speeds up the passage of food through the digestive tract, preventing constipation. Bacteria living on the fibre in the large intestine produce some vitamins as well as gases.

appendix
a small tube-shaped sac attached to, and opening into, the lower end of the large intestine

fibre
the indigestible parts of plants



▲ FIGURE 11.2.5 The inside of the large intestine has many blood vessels to enable absorption of water and other substances.

The rectum and the anus

At the end of the large intestine is the rectum. The rectum is a storage facility that can stretch to hold undigested material, called **faeces**. At the end of the digestive tract is the **anus**, through which faeces leave the body. When a **bowel motion** occurs, the anal sphincter – which is a specialised muscle that is normally closed – opens to allow waste to be **egested**.

How do we compare?

Most people have an **omnivorous** diet that includes food sourced from both plants and animals. The human digestive system is suited to this diet. The digestive systems of other animals are also suited to their own diets.

Koalas, for example, have a **herbivorous** diet that is restricted to the leaves of certain eucalyptus trees. These leaves are very tough and difficult to digest and are low in protein and energy. Koalas have sharp front teeth to clip leaves. Their back teeth are flat and wide for grinding the leaves (Figure 11.2.6a). The chewed material passes down the koala's oesophagus to the stomach and then into the small intestine. Between the small and large intestines is the **caecum**, which receives undigested food material from the small intestine.

faeces

undigested waste material

anus

the external opening of the rectum, through which faeces leave the body

bowel motion

the process of egesting faeces through the anus

egest

to pass out of the body

omnivorous

describes an organism that feeds on both plants and animals

herbivorous

describes an organism that feeds on plants only

caecum

a pouch or large tube-like structure at the beginning of the large intestine; receives undigested food material from the small intestine



▲ FIGURE 11.2.6 (a) A koala's teeth are suited to its diet of eucalyptus leaves. (b) A dingo's teeth are suited to its diet of meat.

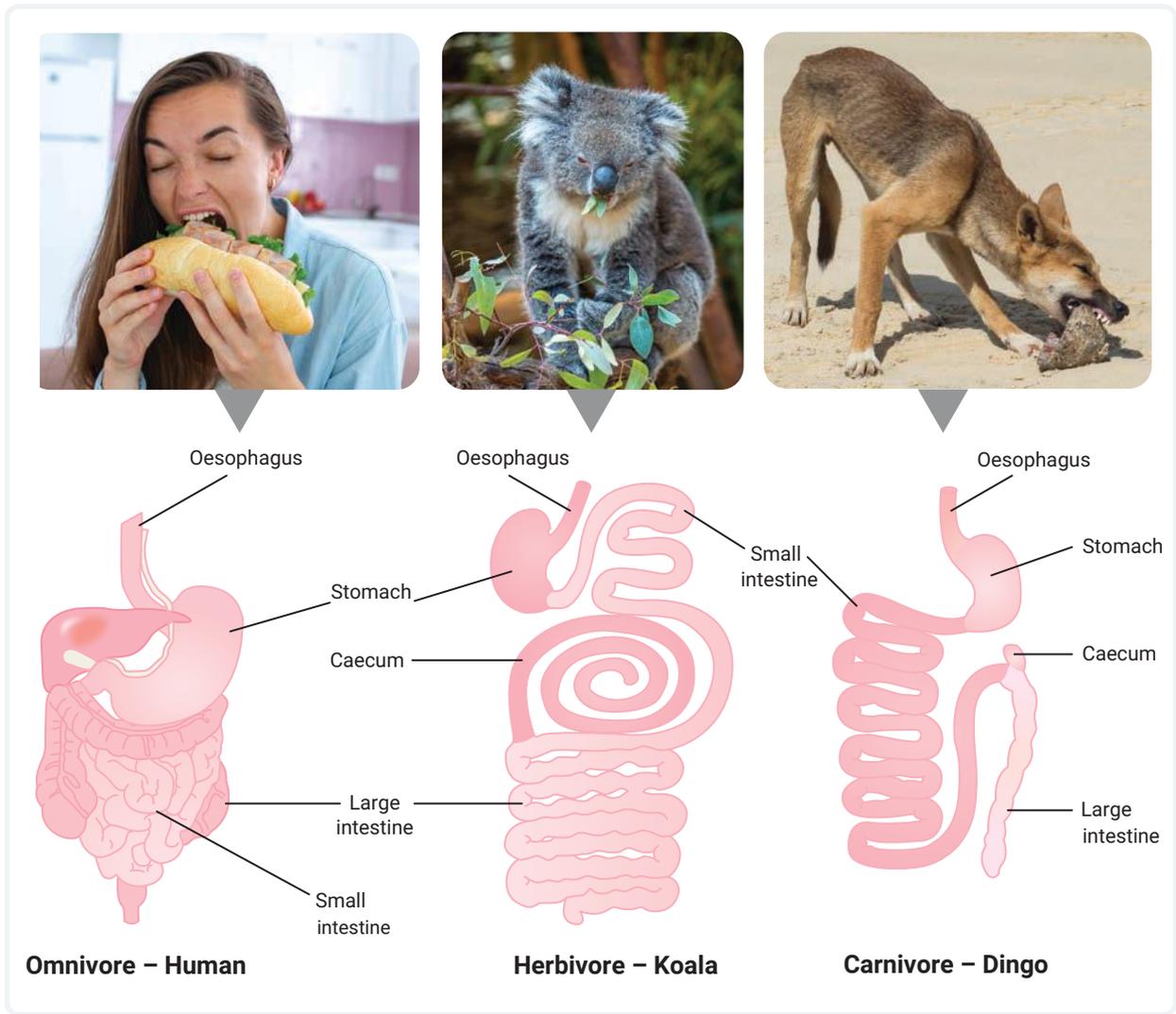
Humans also have a caecum, but it is underdeveloped. In koalas, the caecum is 2 metres long (Figure 11.2.7). It contains cellulose-digesting micro-organisms that break down the cell walls of the eucalypt leaves. This releases the nutrients within the cells for use by the koala.

Dingoes have a **carnivorous** diet that includes rabbits, possums and kangaroos. The teeth of a dingo are those of a hunter. Their incisors at the front of the jaw are used for nibbling and stripping meat. Their curved canines are used for holding objects and tearing meat. Molars at the back of the jaw are used for crushing and grinding.

Dingoes have a long small intestine (Figure 11.2.7), which is important for digesting and absorbing the fat and protein in meat. Unlike koalas, they have a very small caecum and large intestine because they eat very little plant material.

carnivorous

describes an organism that feeds on animals only



▲ FIGURE 11.2.7 The digestive systems of omnivores, herbivores and carnivores suit their diets.

11.2 LEARNING CHECK

- 1 What is the role of the digestive system?
- 2 What are enzymes? What is their role in digestion?
- 3 **Explain** the difference between mechanical digestion and chemical digestion. **Name** an example of each from the human digestive system.
- 4 **Explain** why it is important for our body's digestive system to break down complex foods into their simpler forms.
- 5 Where is water absorbed along the digestive tract?
- 6 What is the role of a sphincter? Is its structure suited to its function? **Explain** your answer.
- 7 **Construct** a table.
 - a In the first column of the table, place the following organs in their correct order from mouth to anus: mouth, large intestine, stomach, rectum, oesophagus, caecum, small intestine, anus.
 - b In the second column of the table, **describe** the function of each of these organs.



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ modelling the process of digestion in the mouth
- ▶ identify the structures and functions of digestion in the mouth
- ▶ explaining the action of saliva and salivary amylase in the mouth
- ▶ describing the validity of the mouth model that you investigated.

THE STRUCTURE AND FUNCTION OF THE MOUTH

AIM

To explain the action of saliva and salivary amylase in the mouth

MATERIALS AND EQUIPMENT

- 1 apple or other hard fruit
- 1 savoury biscuit

! Safety

Let your teacher know if you have any allergies to the fruit or biscuits used in the investigation.

Wash your hands well before and after the investigation.

PART A: EATING AN APPLE

PROCEDURE

- 1 Eat a small piece of apple or other hard fruit.
- 2 Make careful observations about what each part of your mouth does as you bite, chew and swallow the fruit.
- 3 Consider what is added to the food as you chew.
- 4 Write down the functions carried out by the lips, teeth (incisors and canines) and tongue.

ANALYSIS

- 1 What is the role of saliva?
- 2 Why do we have different kinds of teeth?
- 3 What is the function of the mouth in eating?

EXTENSION

- 4 Compare the mouth, and in particular the teeth, of a lion, piranha and human.

PART B: EATING A BISCUIT

PROCEDURE

- 1 Put a savoury biscuit in your mouth and chew for as long as possible before swallowing.
- 2 Carefully observe and record any changes in taste as you chew the biscuit.

ANALYSIS

- 1 What is the role of saliva?
- 2 Did you notice any change in the biscuit's taste as you chewed? If so, why do you think this happened?
- 3 What substance in your mouth would have caused this change?
- 4 Was your model of the function of the mouth valid? Why?

CONCLUSION

Write a valid conclusion for this investigation. Refer to the aim and compare the results of the two investigations.

11.4 Respiratory system

BY THE END OF THIS MODULE YOU WILL BE ABLE TO:

✓ explain how the structures of cells and organs are related to their functions in the respiratory system.



Video activity
How does COVID affect the lungs?

Extra science investigation
Lung capacity

GET THINKING

People sometimes describe rainforests as Earth's lungs. What do you think is meant by this? How do you think a forest is the same as our respiratory system? How is it different?

As you saw in Module 7.5, when glucose is broken down during cellular respiration, oxygen is consumed and carbon dioxide and water are produced. The role of the respiratory system is to bring oxygen into the body and to remove the waste carbon dioxide.

Breathing

Air enters the body through the mouth and nasal passages and moves into the lungs. This process is called **inspiration**, or breathing in. As the air enters the body, it is warmed and moistened. On **expiration**, or breathing out, air is forced out of the lungs. Muscles in the chest and the **diaphragm** are responsible for increasing and decreasing the size of the chest cavity so that air is pushed in and out (Figure 11.4.1).

During inspiration, air passes into the windpipe, or **trachea**. The trachea is a long tube running from the back of the nasal passage to the **bronchi** (singular: bronchus). Rings of **cartilage** around the trachea and bronchi provide support to keep these tubes open. Each bronchus, formed by the branching of the trachea, takes the air deep into each lung.

inspiration

breathing in

expiration

breathing out

diaphragm

a sheet of muscle under the lungs that assists with inhalation and exhalation

trachea

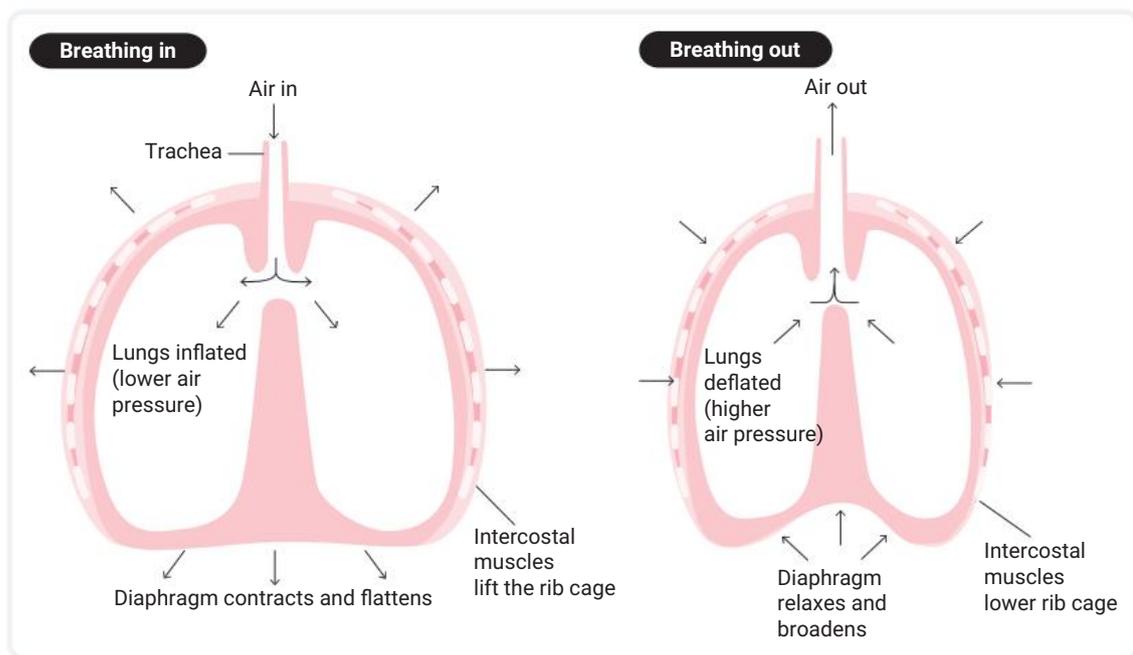
a tube that runs from the back of the throat to the bronchi

bronchi

tubes that branch off the trachea to the left and right lung (singular: bronchus)

cartilage

flexible tissue that makes up part of the skeleton



▲ FIGURE 11.4.1 Breathing in and out involves muscles lifting and lowering the rib cage.

Gas exchange

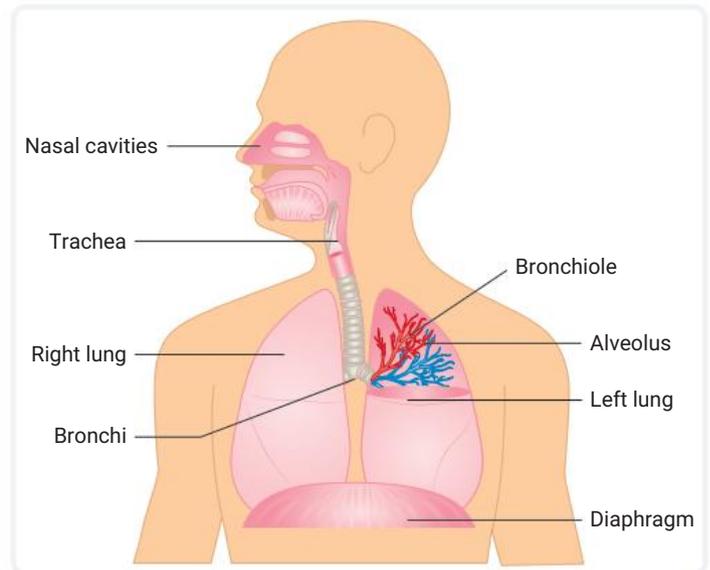
The bronchi branch into **bronchioles**, which are smaller tubes that continue branching into even smaller tubes until they end in **alveoli** (singular: alveolus) (Figure 11.4.2). The alveoli are very small sac-like structures surrounded by very small blood vessels called capillaries (Figure 11.4.3). The alveoli have a moist surface to help with oxygen uptake. The oxygen in the air within the alveoli dissolves into the moist surface. This allows the oxygen to diffuse across the alveoli and capillary surfaces and enter the bloodstream. Waste carbon dioxide in the bloodstream moves the opposite way, from the blood to the air inside the alveoli. From here, carbon dioxide travels back up the bronchioles, bronchi and trachea and is breathed out when you exhale (breathe out).

The shape and number of the alveoli provide a huge surface area for gas exchange. If the whole surface of the alveoli in a human were laid out flat, it would cover approximately 140 square metres: the size of a tennis court. This large surface area allows enough oxygen into – and carbon dioxide out of – your body for your cells to continually carry out cellular respiration.

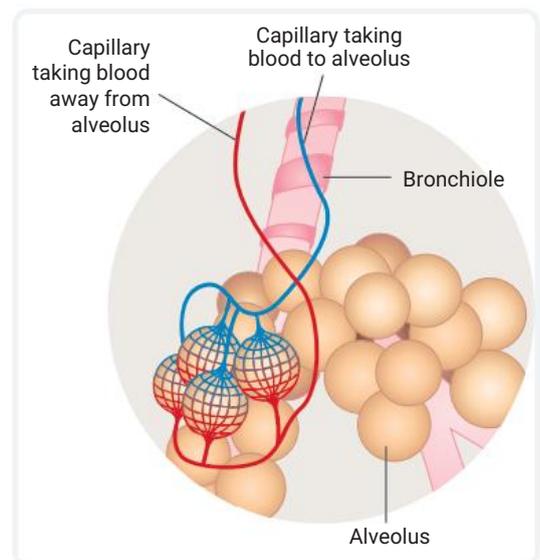
Inspired and expired air contain different percentages of oxygen and carbon dioxide, as shown in Table 11.4.1.

▼ **TABLE 11.4.1** The approximate composition of inhaled and exhaled air

	Nitrogen (%)	Oxygen (%)	Carbon dioxide (%)
Inspired air	78	21	0.04
Expired air	78	14	4.40



▲ **FIGURE 11.4.2** The structure of the human respiratory system



▲ **FIGURE 11.4.3** An alveolus, showing the close connection to the circulatory system

11.4 LEARNING CHECK

- 1 **Describe** the journey of an oxygen particle from the air to an alveolus.
- 2 **Explain** why the:
 - a composition of exhaled (expired) air is different from that of inhaled (inspired) air.
 - b percentage of nitrogen in inhaled air and exhaled air does not change.
- 3 Why is a large surface area important in the respiratory system?
- 4 **Describe** how gases move between the air inside an alveolus and the blood.

bronchiole

a smaller tube connected to the bronchi where they divide

alveoli

air sacs at the ends of the bronchioles in the lungs (singular: alveolus)



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ writing a discussion for an investigation
- ▶ describing the effect of exercise on the ability to hold your breath

The discussion is one of the most important parts of a science report. It can also be the most difficult part to write. Here are some important tips to follow when writing your discussion.

- 1 Link the results back to the testable question or hypothesis. You do this by stating whether your findings support or disprove the hypothesis.
- 2 A good discussion explains the results. A great discussion will also link your findings to a broader context.
- 3 Explain why the results are important.
- 4 Acknowledge the limitations of the investigation.
- 5 Make recommendations on how to improve the investigation for next time.



Video
Science skills in a minute: Writing a discussion

Science skills resource
Science skills in practice: Discussions in science reports

DOES EXERCISE AFFECT YOUR ABILITY TO HOLD YOUR BREATH?

BACKGROUND

The levels of carbon dioxide, and to a lesser extent oxygen, in the blood are important factors in our rate of breathing. If the carbon dioxide concentration is too high, the brain sends impulses to the muscles of the ribs and diaphragm to contract. This brings fresh air into the lungs and increases the rate at which carbon dioxide is lost in exhaled air. The overall effect is a lowering of the carbon dioxide concentration in the blood.

AIM

To investigate the effect of the duration of exercise on breath-holding ability

MATERIALS AND EQUIPMENT

- 2 stopwatches

PROCEDURE

- 1 Work in groups of three. One person times and records the duration of exercise, one person times and records the duration of breath-holding and the other person is the subject. Rotate through these roles if time permits.
- 2 Before you start, read Table 11.5.1, which shows how to control important variables.

Safety

Anyone with a medical issue – for example, asthma – should take the role of recorder and should not be the subject of this investigation.

▼ **TABLE 11.5.1** The ways in which variables should be controlled throughout the investigation

Variable	How to control the variable
Intensity of exercise	Moderate jogging on the spot
Time between exercise	Wait 1 minute before doing the next bout of exercise
Depth of breath before holding the breath	Inhale gently before holding the breath
Amount of clothing	Either remove warm clothing before starting or leave it on throughout

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

Duration of exercise (minutes)	Length of breath holding (seconds)			
	Subject 1	Subject 2	Subject 3	Average
0				
0.5				
1				
2				
3				
4				

- 4 Determine a resting (duration of exercise: 0 seconds) breath-holding ability by timing how long the subject can hold their breath while sitting down, without having exercised. Record the result. Allow the subject to rest for 1 minute.
- 5 The subject exercises by jogging moderately on the spot for 30 seconds (duration of exercise: 0.5 minutes). As soon as the subject stops exercising, the other timer checks how long they can hold their breath. Record the result.
- 6 Allow the subject to rest for 1 minute.
- 7 Repeat Step 5, with the subject exercising for 1 minute. Repeat for exercise sessions of 2, 3 and 4 minutes.
- 8 Repeat steps 4–7 for a different subject. Test as many subjects as possible.
- 9 Using the results you recorded:
 - a calculate an average across all subjects for each exercise condition.
 - b graph the results using a line graph.

ANALYSIS

Write a science report for this experiment. Use your responses to the questions below to write the discussion.

- 1 What trend can you see in your results?
- 2 What trends did other groups see in their results?
- 3 Using your knowledge of the respiratory system, explain your results.
- 4 Discuss your results – i.e. say whether you think your results are reliable and valid, giving reasons.
- 5 Suggest two ways to improve your investigation.

CONCLUSION

Write a conclusion that summarises your findings. Make sure it relates to your aim.

11.6 Circulatory system

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

✓ explain how the structures of cells and organs are related to their functions in the circulatory system.



Video activity
The heart

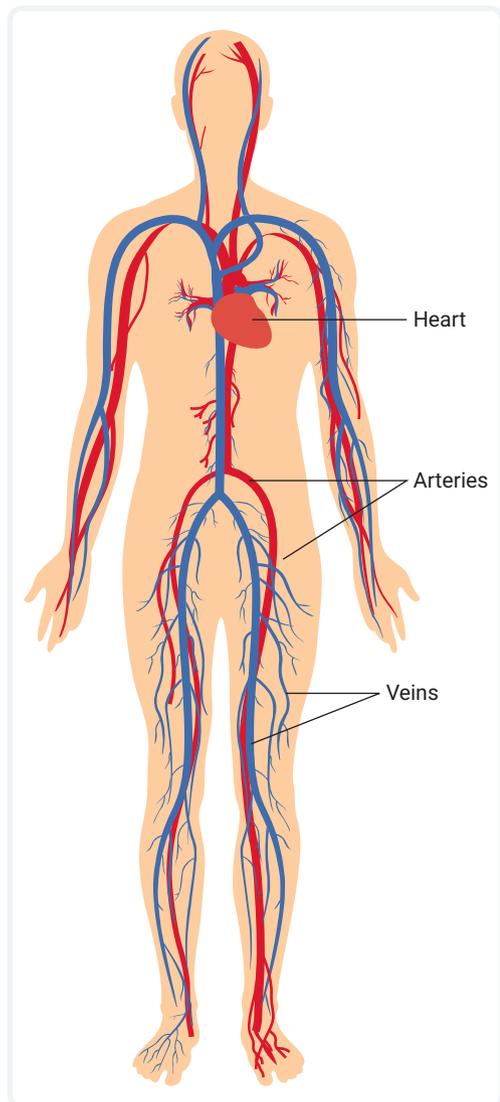
Interactive resource
Crossword: The heart

Extra science investigation
Heart dissection

GET THINKING

Look at the glossary terms in the margins in this module. Are you familiar with some of the terms? Are there any terms that you would like to know more about?

The human circulatory or cardiovascular system is made up of the heart, blood vessels and blood (Figure 11.6.1). The circulatory system links all of the systems of the human body. It transports oxygen from the lungs and the products of digestion directly to cells. It also takes away waste from cells and transports it to the lungs and kidneys for removal from the body.



▲ FIGURE 11.6.1 The human circulatory system. Veins (coloured blue) transport blood to the heart, and arteries (coloured red) transport blood from the heart.

The heart

The heart is a muscular pump about the size of your fist. It is located between your lungs, slightly to the left of centre. The heart has a natural pacemaker that keeps it pumping regularly. Table 11.6.1 shows that heavy exercise can raise the heart rate and increase the volume of blood pumped through it.

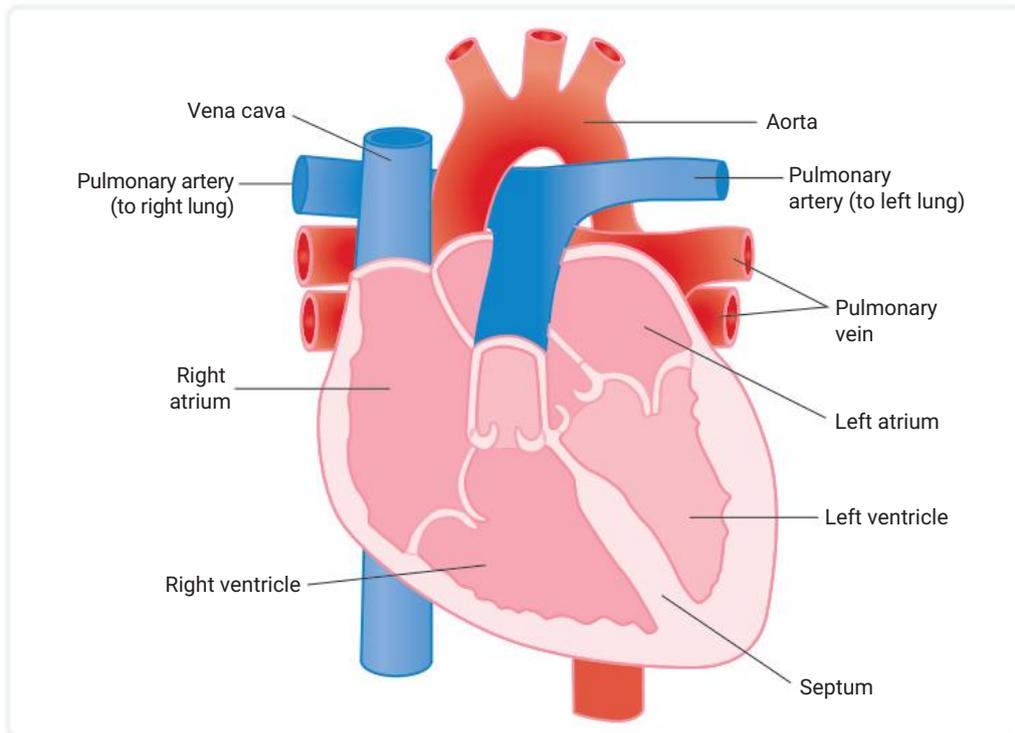
▼ TABLE 11.6.1 Typical heart rate and blood volume pumped at rest and during heavy exercise

	Heart rate (beats/min)	Volume of blood pumped out for each ventricular contraction (mL)	Volume (L/min)
At rest	70	70	4.9
Heavy exercise	180	160	28.8

Figure 11.6.2 shows the structure of the heart and the blood vessels entering and leaving the heart. The heart is divided into four sections, or **chambers**. The two chambers at the top of the heart are the **atria** (singular: atrium). The two chambers at the bottom of the heart are the **ventricles**. The walls of the atria and ventricles are different thicknesses. The atria have thin muscular outer walls compared with the thick muscular walls of the ventricles. The ventricle chambers require thicker walls because they need to pump blood much further and with more force than the atria.

Blood circulation

It is usual to refer to the left and right sides of your heart as they are located in your body. That is, the right side of the heart is on the right side of your body and the left side is on the left of your body.



▲ FIGURE 11.6.2 The structure of the human heart

Blood from the body enters the right atrium from two large, thin-walled vessels called the **vena cava**. This blood is low in oxygen (coloured blue in Figure 11.6.2) because the oxygen has been used up by the cells in the body. It also contains high levels of carbon dioxide. The blood is under low pressure because much of it has moved up from below your heart. Once in the heart, the blood moves from the right atrium, down through a one-way valve, into the right ventricle. From here, the blood is pumped through another one-way valve into the **pulmonary artery** to travel to the lungs.

In the lungs, waste carbon dioxide is removed from the blood and oxygen is added to it. Oxygenated blood returns from the lungs in the **pulmonary vein** and enters the left atrium. Blood then moves through another one-way valve into the left ventricle. When the ventricle contracts, blood is pumped through yet another valve into the **aorta**, to begin its journey around the body. In Figures 11.6.2 and 11.6.3, you will notice that the wall of the left ventricle is thick and muscular. This ensures that blood can be pumped with enough force to travel all the way around the body. Blood on the right side of the heart never mixes with blood on the left side of the heart. A wall down the middle of the heart keeps both sides separate. This wall is called the **septum**.

There are four valves in the human heart; one at the exit of each chamber. Heart valves are made of flaps of tissue that only open in one direction. If blood tries to flow backwards, the valve will snap shut, preventing back flow.

chamber

one of the compartments that form the structure of the heart; there are four chambers in the human heart

atria

the two upper chambers in the human heart, which receive blood from veins (singular: atrium)

ventricles

the two lower chambers in the human heart, which pump blood to either the lungs or the rest of the body

vena cava

a large vein in humans that brings blood to the heart from all parts of the body

pulmonary artery

a blood vessel in humans that takes blood from the heart to the lungs

pulmonary vein

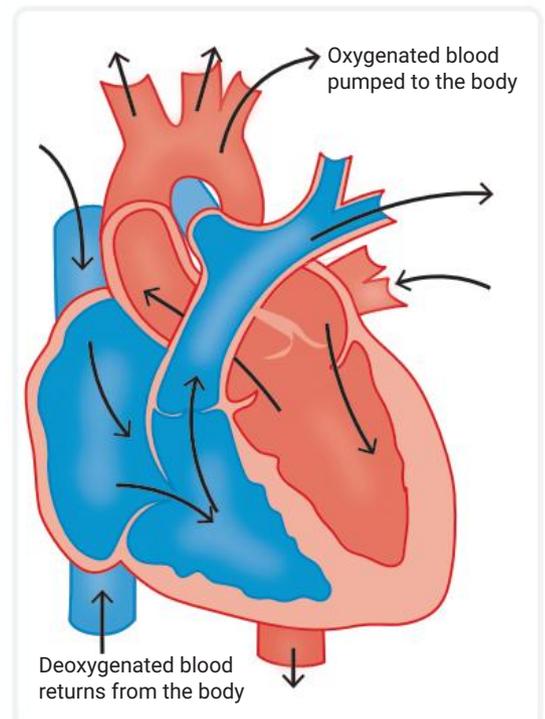
a blood vessel in humans that returns blood from the lungs to the heart

aorta

a large artery in humans that takes blood from the left side of the heart to the body

septum

the dividing wall between the left and right sides of the human heart



▲ FIGURE 11.6.3 The circulation of blood through the left and right sides of the heart

Blood vessels

artery

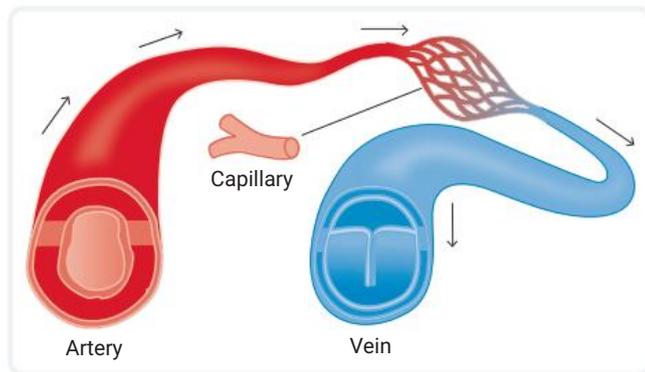
a blood vessel in humans that carries blood away from the heart

vein

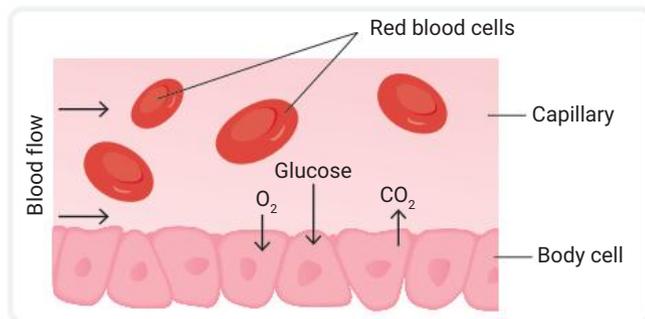
a blood vessel in humans that carries blood to the heart

The major types of blood vessels are (Figure 11.6.4):

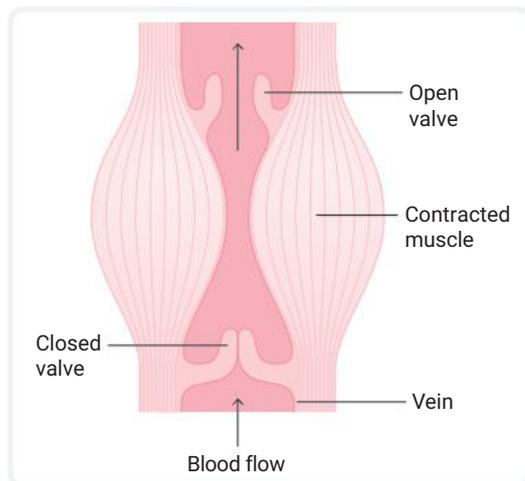
- **arteries** – the vessels that carry blood *away from* the heart
- **veins** – the vessels that carry blood *to* the heart
- **capillaries** – the very small vessels that intertwine with your cells. It is here that oxygen and carbon dioxide move between blood and tissues.



▲ FIGURE 11.6.4 The major types of human blood vessels



▲ FIGURE 11.6.5 Glucose and oxygen move into the cells while carbon dioxide moves out.



▲ FIGURE 11.6.6 The valves in a vein control the direction of blood flow.

Arteries and veins have different structures to accommodate the different pressures of blood flowing through them. Arteries have thick, muscular walls to withstand the high pressure used to pump blood away from the heart.

Blood is pumped from the left side of the heart into the aorta – a very large, thick-walled artery. From here, the blood moves into smaller and smaller arteries, finally entering capillaries. Capillaries are found in every tissue of the body. Materials are exchanged within capillaries. Glucose and oxygen move into the cells to be used in cellular respiration, while waste carbon dioxide moves out of the cells into the blood (Figure 11.6.5).

Blood from tissues travels in the veins back to the heart. As veins contain blood at lower pressure, they have thin walls. These walls can stretch and sometimes blood pools in them, rather than continuing to flow through the vessel. Veins contain one-way **valves** to stop blood from the lower body moving in the wrong direction (Figure 11.6.6).

A valve is a device that ensures that substances flow in one direction. Contracting and relaxing leg muscles also helps to push blood along the veins back to the heart.

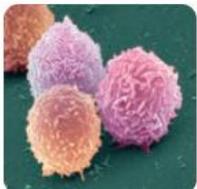
Blood

Blood is the transport fluid that links all of your organs. It carries oxygen and nutrients to every part of your body and transports waste away. There are approximately 5 litres of blood in your body, confined to blood vessels, unless they are damaged by injury.

Blood is made up of various components (Table 11.6.2). **Plasma** is the straw-coloured watery component. It contains glucose, proteins, **hormones** and carbon dioxide. Hormones are chemical messengers that control and regulate certain cells and tissues. **Red blood cells** are also in the plasma. They contain **haemoglobin** that

attaches to oxygen to transport it around the body. **Platelets** are cell fragments that assist in clotting blood in a wound. **White blood cells** are mostly involved with fighting infection as part of the **immune system**. You will learn about the immune system in Stage 5.

▼ TABLE 11.6.2 The components of human blood

Constituent	Appearance	Features	Function
Plasma		Makes up about 55% of the volume of blood Consists of 90% water with nutrients, including proteins, glucose, minerals, hormones and carbon dioxide	A body fluid Carries blood cells and other substances around the body
Red blood cells		Make up 40–45% of the volume of blood Have no nucleus and a limited life span of 3–4 months Made in the bone marrow	Carry oxygen bound to haemoglobin in their cells
White blood cells		Make up about 1% of the volume of blood Made in the bone marrow	Defend the body against disease
Platelets		Make up less than 1% of the volume of blood Cell fragments Survive about a week	Blood clotting

capillary

a very small blood vessel in humans, located in between the smallest arteries and smallest veins

valve

a structure in the human heart and veins that prevents backflow of blood

plasma

the watery component of human blood, in which blood cells are suspended

hormone

a chemical messenger

red blood cell

a blood cell that carries oxygen

haemoglobin

the component of red blood cells that binds with oxygen

platelets

fragments of cells that act in blood clotting

white blood cell

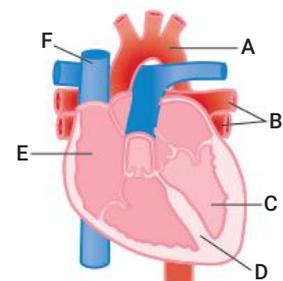
a blood cell that is part of the human immune system

immune system

a complex system that defends the human body against infection and disease

11.6 LEARNING CHECK

- 1 What three components make up the circulatory system?
- 2 **Outline** the role of the blood in supplying your body with its requirements and removing waste.
- 3 If a person had more white blood cells than normal in their blood, what conclusion could you come to?
- 4 Refer to the figure of the heart.
 - a **Name** the structures labelled A–F.
 - b Trace the path of blood through the heart by listing, in the correct order, the structures in the diagram starting from F.
- 5 What would happen if one of the valves in your heart became a two-way valve?
- 6 **Explain** the benefit of an increase in heart rate during heavy exercise.



BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ explain how the structures of cells and organs are related to their functions in the excretory system.



Video activity
The kidneys

Extra science investigation
Kidney dissection

GET THINKING

Imagine that you are marooned at sea in a lifeboat a long way from shore. There is no fresh water available. Should you drink seawater? Could you excrete that much salt?

Waste removal

The human body is not 100 per cent efficient at converting raw materials into useful substances or energy. Unwanted materials, called waste, are removed from the body in the process of **excretion**. One such waste is **urea**, a toxic substance produced in the breakdown of excess amino acids. Other materials that are excreted from the body include water and salts that have been taken in from food.

In mammals, the organs that excrete waste are the **kidneys**, lungs and skin. You already know that the lungs excrete carbon dioxide during exhalation. Both the skin and the kidney excrete urea, water and salts, including sodium chloride. Excretion by the skin takes place during sweating (Table 11.7.1).

excretion

the process of eliminating or expelling waste matter

urea

nitrogenous waste that is produced as amino acids are broken down in the human body

kidneys

the excretory organs of mammals

▼ TABLE 11.7.1 Typical values for water intake and output in humans

The ways water enters the body	Volume (mL)	The ways water leaves the body	Volume (mL)
Drink	1400	Urine	1500
Food	800	Sweat	450
From cellular respiration	300	Breath	450
		Faeces	100
Total	2500	Total	2500

This module will focus on the role of the excretory system in excretion. As well as excreting waste, the kidneys also maintain the delicate balance between the amount of water in the blood and the concentration of solutes dissolved in it.

Kidney function

The kidneys are two bean-shaped organs located at the back of the upper abdomen. The renal artery is a branch of the aorta that brings oxygenated blood containing waste to the kidneys. The renal vein takes deoxygenated, filtered, clean blood from the kidneys back into general circulation (Figure 11.7.1).

nephron

the structure in the human kidney where filtration of the blood occurs

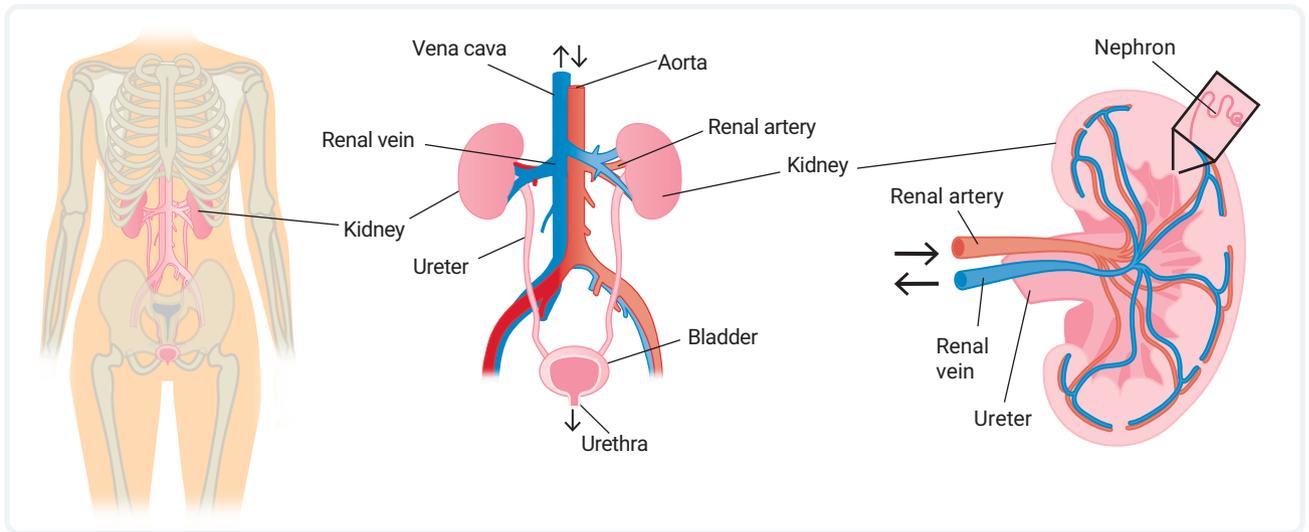
filtration

the process in the kidney where all materials, except for protein and blood cells, are forced out of the bloodstream

Formation of urine

Waste is removed from the blood by tiny structures in the kidneys called **nephrons**.

During **filtration**, the blood capillaries and tubules of the nephrons are responsible for



▲ FIGURE 11.7.1 The human excretory system

removing both waste and useful material from the blood. Then, as these materials move through the nephron, blood reclaims the useful substances, as well as some water and solutes from the tubules.

Waste, such as urea, is not reabsorbed into the blood. Instead, the urea leaves the kidney dissolved in **urine**. A tube, called the **ureter**, carries urine from each kidney to the bladder. The bladder stores urine until it is removed from the body via a single tube called the **urethra** (Figure 11.7.1).

The amount of water consumed in food and drink can vary. The body, via the kidneys, adjusts for excess water intake by increasing urine output. Conversely, it adjusts for increased exercise or decreased water intake by reducing urine output. Therefore, the kidneys not only prevent the build-up of waste in the body, they also help maintain water balance by controlling the volume, composition and pressure of body fluids.

urine

liquid containing multiple waste products, especially urea

ureter

the tube that carries urine from the human kidney to the bladder

urethra

the tube that carries urine from the bladder to the outside of the human body

11.7 LEARNING CHECK

- List** wastes that need to be excreted from the body and name the organs that remove them.
- State** the functions of the:
 - kidney.
 - urethra.
 - bladder.
- Describe** the role of a nephron.
- Predict** the effect of each of the following on the amount and concentration of urine.
 - Playing tennis
 - Having a bath
 - Drinking a large volume of soft drink
- Kidneys only remove waste. **Explain** why this statement is not true.



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ creating a 3D model of the excretory system by using recyclable materials
- ▶ assessing scientific models.

Models in science can be visual, simple representations of processes or concepts. Models often explain how something works and we use them to make predictions. Models can be very useful but they can have limitations, especially when the concepts or processes shown by the model are complicated or have many steps to follow.

In this investigation, you will be making a model. You can assess your model by asking the questions below.

How well does your model represent and explain the concept or process?

Observe how your model works. Compare your observation with a description of the concept or process that your model intends to explain.

What are the limitations of your model?

Think about the ways that your model does *not* show the concept or process. Maybe it is too simple or some steps of the process are not clearly shown or not represented at all.

How can you improve your model?

There are many ways you can improve your model, such as using different materials or adding an extra step. You can also change to a different type of model, such as using a mathematical model or using a digital model instead of a physical model.



Video
Science skills
in a minute:
Assessing
models

**Science skills
resource**
Science skills
in practice:
Assessing
scientific
models

MODELLING KIDNEY FUNCTION

AIM

To create and assess a model that represents the function of the kidney

BACKGROUND INFORMATION

In this investigation, you will be modelling the function of the kidneys. You will do this by using two types of 'urine': normal urine (modelled with coloured water) and urine containing high levels of fat (modelled with coloured water and sand).

MATERIALS AND EQUIPMENT

- | | |
|---|---|
| <input checked="" type="checkbox"/> 2 small plastic bottles | <input checked="" type="checkbox"/> 3 × 250 mL beakers |
| <input checked="" type="checkbox"/> 2 filter papers | <input checked="" type="checkbox"/> 1 L of water |
| <input checked="" type="checkbox"/> 2 fine wire mesh | <input checked="" type="checkbox"/> yellow food colouring |
| <input checked="" type="checkbox"/> 1 m of aquarium tubing | <input checked="" type="checkbox"/> fine-grained sand |
| <input checked="" type="checkbox"/> 2 retort stands | <input checked="" type="checkbox"/> electrical masking tape |
| <input checked="" type="checkbox"/> 2 clamps | <input checked="" type="checkbox"/> scissors |
| <input checked="" type="checkbox"/> funnel | <input checked="" type="checkbox"/> safety goggles |

Safety

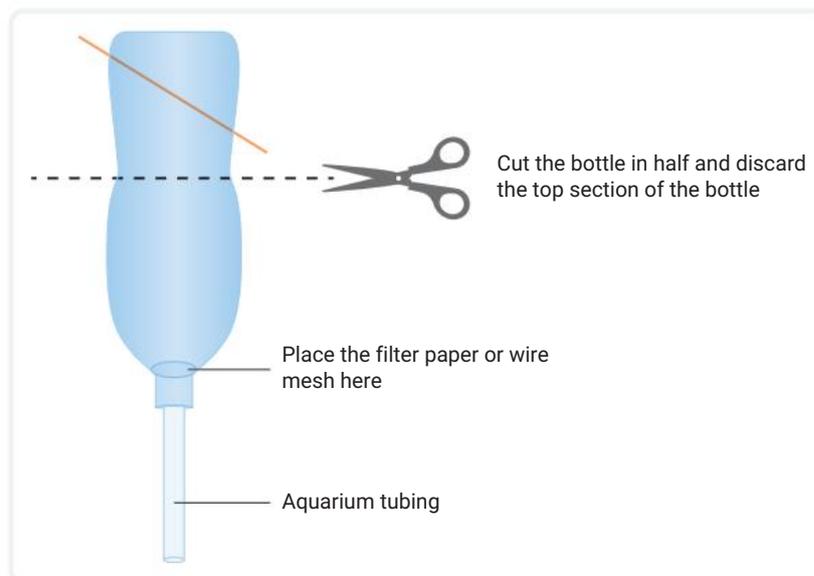
Manage sharp equipment with care to avoid cuts. Wear goggles at all times to protect your eyes from sand particles and splashes of the yellow food colouring.

PROCEDURE

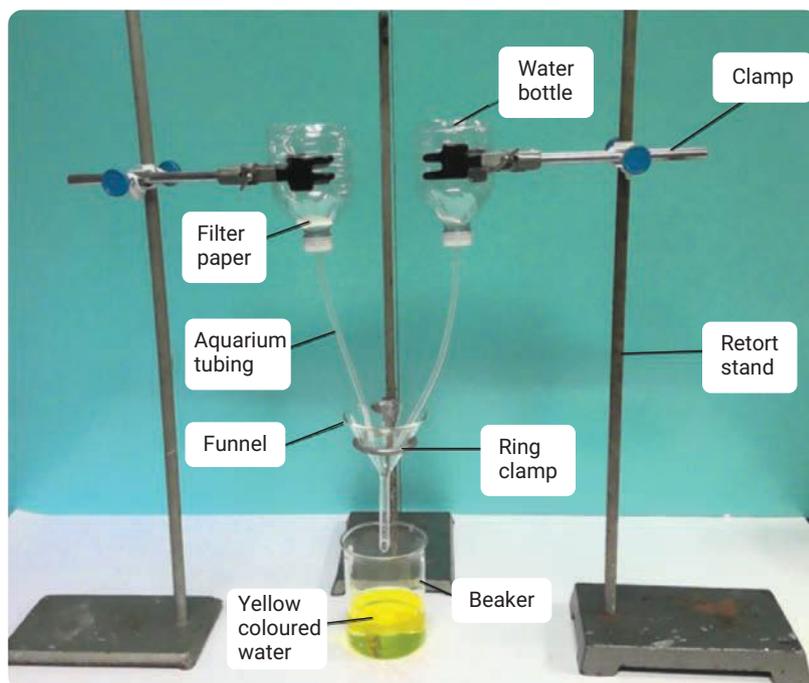
Before you begin the procedure, predict what you think will happen when you pour the two types of 'urine' through the model with filter paper. Also predict what will happen when you use the mesh instead of the filter paper.

Making the model

- 1 Cut two plastic bottles in half, as shown in Figure 11.8.1. Discard the bottom half of the bottles.
- 2 Cut four circular pieces of filter paper. Place one of them inside each bottle at the end of each bottle where the lid was, to cover the small hole (Figure 11.8.1). You will use the other two pieces when you repeat the experiment. The bottles with filter paper represent the kidneys.
- 3 Cut four circular pieces of the wire mesh. You will use these to replace the filter papers later on in the investigation.
- 4 Make a hole in the lid of each water bottle and insert the 40 cm long piece of aquarium tubing. Secure the tube with electrical masking tape. The tubes represent the ureters.
- 5 Secure the bottles on each retort stand with the clamps.
- 6 Place the funnel inside one of the beakers and under the two retort stands. This is the bladder.
- 7 Place the pieces of aquarium tubing inside the funnel and secure them with the electrical masking tape. Figure 11.8.2 shows what your model should look like.
- 8 To make the first lot of 'urine', place 100 mL of water in a beaker and add a few drops of yellow food colouring.
- 9 In a second beaker, add 100 mL of water and two teaspoons of fine sand. This is the second lot of 'urine.'



▲ FIGURE 11.8.1 Filter paper position in the bottle



▲ FIGURE 11.8.2 The experimental set-up for the kidney model

Modelling kidney function

- 1 Place 50 mL of the first lot of urine, in each bottle.
- 2 Replace the filter paper in the bottles and repeat with the second lot of 'urine', containing sand.
- 3 Record your observations in a table like the one below.
- 4 Carefully replace the filter paper in each bottle with the circles of mesh wire and repeat steps 1–3. Remember to replace the mesh wire when you use the 'urine' with the sand.

RESULTS

Copy and complete the table below with your observations about how each filter type filters the two different types of 'urine'.

Type of filtration	Urine 1 (water + yellow colouring)	Urine 2 (water + yellow colouring + sand)
Filter paper		
Wire mesh		

ANALYSIS

- 1 What function of the kidney did the model represent?
- 2 Could you predict how the model would work?
- 3 How well did your model work? What limitations did you observe in how the model represented the function of the kidney?
- 4 What was the reason for changing the type of filter and type of urine in the model?

CONCLUSION

Write a scientific conclusion for this investigation. Refer to the aim and include your analysis of the model's limitations and how you could improve the model.

DATA SCIENCE



Learn more about analysing scientific models in **Module 2.10**.

11.9 Disorders of body systems

11.9

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe the causes, symptoms and treatment of common disorders of body systems
- ✓ define disease and disorder
- ✓ assess the impact of removing any part of the body.

GET THINKING

In previous modules, we looked at different body systems. Recall the main functions of each of the body systems that you learned about. In this module, you will find out what can go wrong.



Video activity
Heart disease

Disease and disorder

A **disease** is an imbalance or a condition that affects the normal functioning of an organism's organs or systems. A disease usually has an underlying cause. For example, the common cold is caused by a virus and cancer is due to cells growing abnormally.

A **disorder** is a group of symptoms caused by parts of the body or the mind not functioning normally. The cause of a disorder is not always known, but it is sometimes the consequence of a disease. For example, heart arrhythmia is a disorder in which the heart beats abnormally. It is caused by cardiovascular disease, but it is not a disease itself.

disease

an illness that affects the normal functioning of an organ or system

disorder

a group of symptoms that is usually related to a disease

symptom

an indication of a disorder or disease

diagnosis

the identification of the nature of an illness

endoscope

an instrument used to look inside the human body

Symptoms and diagnosis

The first sign of a disorder is usually one or more symptoms. **Symptoms** are the effects on the body of a disorder or disease. Even if you know the symptoms, making a **diagnosis** of an internal disorder is often difficult. Doctors use an **endoscope** to look inside the body without having to perform surgery. Internal abnormalities revealed through endoscopy include inflammation, cancer, polyps, tumours, ulcers and other diseases and conditions.

Kidney stones

Kidney stones form when minerals congregate into masses of crystals in the kidney. They commonly range in size from as small as a grain of sand to as big as a golf ball. Occasionally, stones can become very large, or can travel into the bladder where they may continue to grow (Figure 11.9.1). Very small stones can be excreted in the urine. However, larger kidney stones usually become painful when they move along the ureter or the urethra. The exact cause of kidney stones is not known. The risk of forming kidney stones can be reduced by drinking plenty of water.



iStock/angkhon

▲ **FIGURE 11.9.1** An X-ray of kidney stones and cancerous bladder stones

cholesterol
an insoluble,
waxy substance

risk factor
a condition or behaviour
that increases the
likelihood of a person
developing a disease or
health disorder

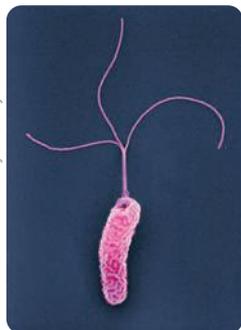
Coronary artery disease

Coronary artery disease occurs when the arteries that supply the heart with blood become blocked. Blockages form when **cholesterol** builds up on the walls of the coronary blood vessels, allowing less blood to pass through. If the blood vessel becomes completely blocked, an area of the heart is deprived of blood supply, resulting in tissue damage. This leads to a heart attack. Symptoms of a heart attack include sudden onset of chest pain, breathlessness, nausea and cold, clammy skin.

Risk factors can increase a person's chance of developing coronary heart disease. Some factors, such as age, sex or family history, cannot be altered. Other factors, such as smoking and not getting enough exercise, are under our control. Medication can reduce risk factors such as high blood pressure. In some cases, a patient may need surgery to improve the blood flow to the heart.

Peptic ulcers

Peptic ulcers are open, inflamed sores on the lining of the stomach. They are also known as gastric ulcers. Stomach pain is usually the first symptom of a peptic ulcer. Other, less common, symptoms include indigestion, heartburn, nausea, vomiting and loss of appetite. Many ulcers are caused by *Helicobacter pylori* bacteria, which can be treated with antibiotics (Figure 11.9.2).



▲ **FIGURE 11.9.2** The *Helicobacter pylori* bacterium



▲ **FIGURE 11.9.3** A surgeon shows some gallstones from a surgically removed gallbladder.

Removal of organs

When a disease or a disorder affects an organ, the whole system to which the organ belongs will also not function properly. For example, if a person has liver disease, it will affect the function of their entire digestive system. This is because the liver produces bile, which helps digestion. However, some organs can be removed without affecting the function of the entire system. For example, many people have their gallbladder removed due to the presence of gallstones (Figure 11.9.3). In most cases, people's digestive system can function properly without a gallbladder.

11.9 LEARNING CHECK

- 1 Define:**
 - a symptom.
 - b diagnosis.
- 2 Describe** how an endoscope could be used to diagnose a gastric ulcer.
- 3 Explain** why a person can live with only one kidney.
- Copy the following table and **research** the diseases listed.

Disease	Body system	Cause	Symptoms	Treatment
Lung cancer				
Colon cancer				
Nephritis				

11.10 Knowledge of body systems

**IN THIS MODULE,
YOU WILL:**

- ✓ explore Aboriginal and Torres Strait Islander Peoples' long-held understanding of the internal systems of animals.

Understanding internal systems of humans

Prior to European colonisation, Aboriginal and Torres Strait Islander Peoples obtained almost everything they needed to live from Country/Place. They faced and had to overcome many challenges to obtain essential resources, including food, water and medicines.

Aboriginal and Torres Strait Islander Peoples shared their knowledge within and between related cultural groups. This includes groups who shared social, linguistic, spiritual, economic or kinship connections. Knowledge of physiology and medicine has long been shared through cultural narratives and pictorial representations over many generations. Their traditional medical knowledge, accumulated and refined over thousands of years, helped treat ailments and injuries. Aboriginal and Torres Strait Islander Peoples had, and continue to maintain, a detailed knowledge of the medicinal benefits of many plant species. They also developed and used different delivery methods; for example, through ingestion, inhalation or absorption through the skin. This shows the detailed understanding Aboriginal and Torres Strait Islander Peoples have of the human body and how it works.

- 1 **Relate** each delivery method to a specific internal system.
- 2 For one of the identified systems, **explain** how the treatment is delivered into the body.

☆ ACTIVITY 1

Representing internal systems of animals

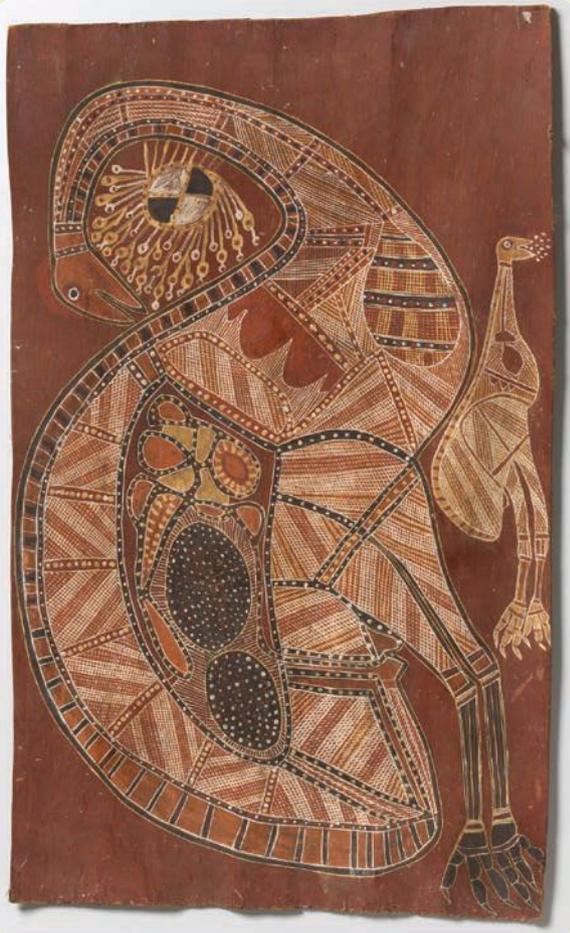
Aboriginal and Torres Strait Islander Peoples have been hunting large animals such as kangaroos and emus for thousands of years, using a variety of methods including fires and nets. Unlike colonists, who primarily hunted native animals for sport or for eradication, Aboriginal and Torres Strait Islander Peoples hunted and killed only what they needed.

Aboriginal hunters had a good understanding of kangaroo physiology. They could identify tracks, how the animal would behave if it detected movement, and where on its body was best to spear it so that the kangaroo died with little suffering. This information was gained through an ongoing cycle of formal instruction, which included demonstration, observation of people with proficient hunting skills and personal practice. It could often take years for a person to become a successful hunter.

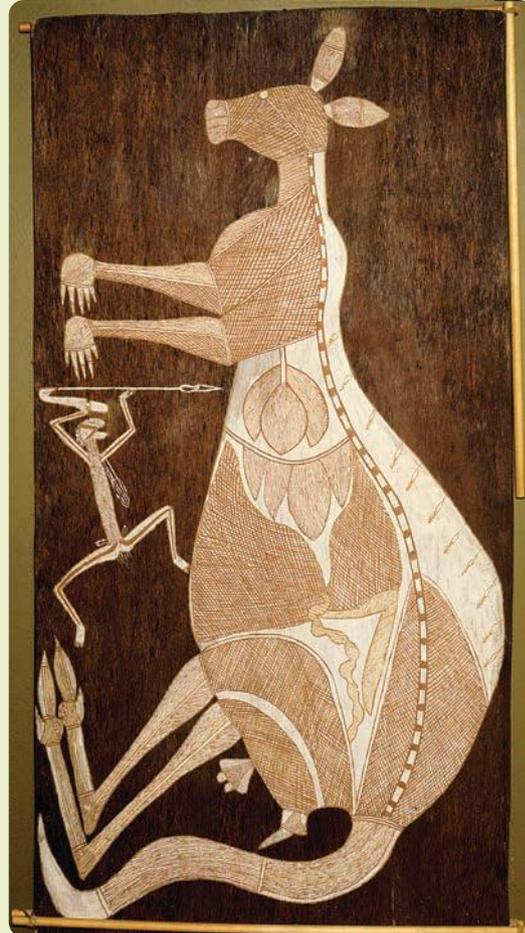
When an animal was killed, nothing was wasted. All the edible parts were eaten, the skin was used to make cloaks and blankets, sinew was used as bindings, and teeth and bones were used as tools and body ornaments. A good understanding of an animal's internal structure is needed in order to remove and use all parts of the animal. For example, Aboriginal and Torres Strait Islander Peoples would be able to locate and carefully remove highly sought-after organs such as the liver and kidneys.

☆ ACTIVITY 2

Yirawala © the estate of the artist, licensed by Aboriginal Artists Agency Ltd/National Gallery of Australia/Purchased 1976 Collected by Sandra Le Brun Holmes, Sydney



▲ FIGURE 11.10.1 An X-ray-style bark painting of two emus by Yirawala, a Kuninjku artist from western Arnhem Land, NT



Heritage Image Partnership Ltd/Alamy Stock Photo

▲ FIGURE 11.10.2 An X-ray style bark painting of kangaroo and hunter from western Arnhem Land, NT; artist unknown

Examine Figures 11.10.1 and 11.10.2.

- 1 **Name** each of the organisms drawn.
- 2 **List** the body systems and organs you can identify in each of the drawings.
- 3 **Explain** how these drawings would help a hunter.
- 4 **Explain** how these drawings would help maximise use of all the animal's parts.
- 5 Research a scientific diagram of the internal organs of one of the organisms you named in question 1 and **identify** similarities with the drawing.
- 6 **Explain** why the type of artwork shown in Figures 11.10.1 and 11.10.2 may be referred to as X-ray art.
- 7 Research the properties of sinew and **explain** why Aboriginal and Torres Strait Islander Peoples used it as bindings.

11.11 Scientists as communicators

BY THE END OF
THIS MODULE, YOU
WILL BE ABLE TO:

✓ explain why it is important for scientists to communicate their findings.

Communicating is an important part of the work of scientists. It allows scientists to have their investigations peer-reviewed and reproduced, source funding for their work, collaborate with other scientists and share what they learn with the wider community and people who need to use their findings. Dame Jane Goodall is an example of a scientist who is an effective communicator.

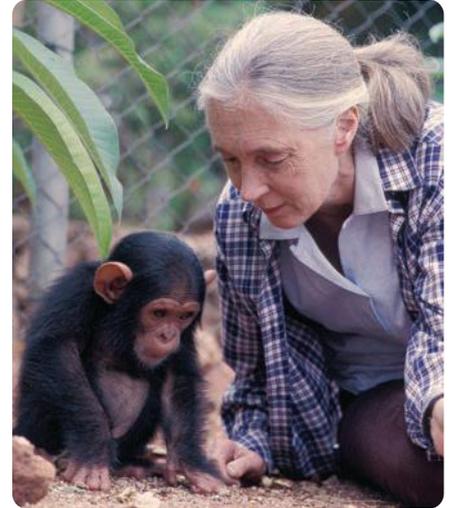
Dame Jane Goodall is well known, not only among scientists, but also by the general public worldwide. In 1957, at the age of 23, Jane began her study of chimpanzees in Africa. By living in the chimpanzees' habitat, she could observe behaviours that hadn't previously been seen, such as eating meat and using tools. These observations changed our understanding of chimpanzees, and our knowledge about the relationships between primates.

In 1963, Jane published an article in *National Geographic* titled 'My Life Among Wild Chimpanzees'. Since then, she has written many articles and more than 25 books. She has inspired many films and has received many awards. Jane Goodall now spends her time travelling to speak about the threats to chimpanzees and the environment, urging audiences to recognise their power to change the world for the better.

The impact that Jane Goodall has had was only possible because she shared her experiences and findings with the wider community. Jane has engaged specific audiences through different communication methods. By adjusting her communication from scientific reports to children's books to popular movies, Jane has been able to share her studies with a lot of people.

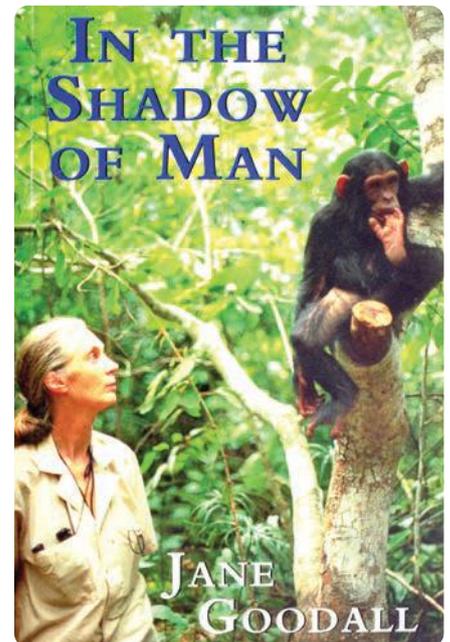
11.11 LEARNING CHECK

- 1 **List** the benefits of scientists communicating with different audiences.
- 2 **Explain** how Jane Goodall has managed to use her studies to promote environmental conservation.
- 3 **Describe** the ways that scientists can communicate with the general public.
- 4 **Choose** one other scientist and **discuss** how they have communicated to drive change.



Avalon/Bruce Coleman Inc/Alamy Stock Photo

▲ FIGURE 11.1.1 Jane Goodall communicated the results of her studies about the behaviour of chimpanzees in Tanzania.



Jonny White / Alamy Stock Photo

▲ FIGURE 11.1.2 One of the books that Jane Goodall has written



Video activity
Science
communication tips

11 REVIEW

REMEMBERING

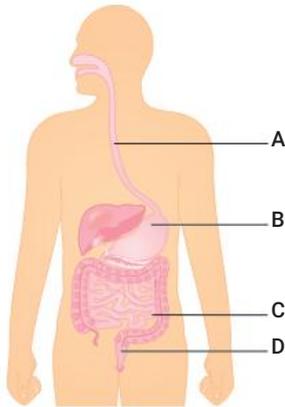
1 **Match** the blood constituent (a–d) to its function (i–iv).

Constituent	Function
a Plasma	i Immune functions
b Red blood cells	ii Fluid medium
c White blood cells	iii Blood clotting
d Platelets	iv Carry oxygen bound to haemoglobin

- 2 **List** three features of the lungs that make them well suited to the job they do.
- 3 **List** examples of omnivorous, herbivorous and carnivorous animals.

UNDERSTANDING

- 4 **Explain** how and why the digestive systems of the koala and the dingo differ from yours.
- 5 Why does peristalsis occur in the digestive tract?
- 6 **Account** for the difference in thickness of the muscular walls of the atria and ventricles.
- 7 **a Name** the system shown in the diagram at right.
b Name the organs labelled A–D.
- 8 **Explain** what happens to the diaphragm during inspiration and expiration.
- 9 **Describe** how Aboriginal and Torres Strait Islander Peoples shared their knowledge of human and animal systems.



APPLYING

- 10 If you were shown a blood vessel attached to the heart, **explain** how you would know whether it was an artery or a vein.
- 11 *Diprotodon* is a genus of extinct giant marsupials. They were herbivores. **Predict** how their digestive system would compare to a modern marsupial.

- 12 **Describe** the pathway of a urea molecule from the aorta to the outside of the body.
- 13 **Explain** why blood oozes out of a wound to a vein but spurts out of a wound to an artery.
- 14 **Apply** your understanding of the excretory system to explain why marine turtles drink only seawater and constantly produce very salty tears.

ANALYSING

- 15 **Explain** how the oesophagus and the small intestine are alike. How do they differ?
- 16 **Compare** mechanical and chemical digestion.
- 17 **Design** a summary table for digestion, listing each organ and its function.
- 18 Where in the body would you expect to find haemoglobin combining with oxygen?
- 19 How do capillaries differ from other blood vessels in their:
a function? **b** structure?

EVALUATING

- 20 Why is it incorrect to say all arteries carry oxygenated blood?
- 21 Peristalsis happens in the oesophagus and in the intestine. **Evaluate** what would happen to the digestion process if peristalsis stopped.
- 22 **Explain** the importance of valves in the heart and veins.
- 23 Each year, many babies are born with a ventricular septal defect, where there is a hole in the septum dividing the ventricles. **Explain** how this could affect blood being pumped out of the aorta.

CREATING

- 24 Systems in multicellular organisms work together so the organism can interact with the environment, survive and reproduce. **Create** an analogy using a city to show how the functions of the circulatory, excretory and digestive systems work together.
- 25 **Create** an interactive model of one of the systems studied in this chapter to show its functions to a 5-year-old child.

SCIENCE IN DEPTH STUDY

#11

1 Connect what you've learned

In this chapter, you've learned about various body systems and their disorders. Create a mind map to show the connections between the information you have learned.

2 Check your thinking

Organ transplants are a way to extend the life of people who have experienced organ failure. However, there are not enough donors to meet the demand. Many companies are working on creating artificial organs in the laboratory.

Research the companies and health institutions that are working to create artificial organs for transplants.

Here are some questions to guide your research.

- How are artificial organs created?
- What types of techniques and materials are used to create the organs? For example, consider 3D printing, and the use of synthetic versus biological materials.

3 Get into action

Choose one artificial organ and find out more about how it is produced in the laboratory.

Are there any human trials happening for this artificial organ? Would the artificial organ be as effective as the natural organ?

Patients who receive an organ from a donor must take medication for the rest of their lives to avoid rejection. Is this the case when receiving an artificial organ? Why?

4 Communicate

Create an infographic or a brochure with detailed information about your research on artificial organs for transplantation. Your infographic or brochure should be suitable for patients to read while in a doctor's waiting room.



12

Plant systems

12.1 Systems in plants (p. 420)

Specialised cells, tissues and organs make up plant systems: leaves, stems and roots.

12.2 Water transport (p. 422)

Plants transport water from their roots to their leaves through the xylem.

12.3 WORKING SCIENTIFICALLY: Observing plant systems (p. 424)

Describing water transport in a plant

12.4 Sugar transport (p. 425)

Plants transport sugar from their leaves to other parts of the plant through the phloem.

12.5 Control of gases (p. 427)

Gas exchange occurs between the air and plants.

12.6 WORKING SCIENTIFICALLY: Developing questions, predictions and hypotheses (p. 429)

Investigating factors affecting stomatal density

12.7 Specialised plant structures (p. 431)

Plants have specialised structures, allowing them to live in many different environments.

12.8 WORKING SCIENTIFICALLY: Using a microscope to observe and draw (p. 434)

Specialised plant structures under the microscope

12.9 ABORIGINAL AND TORRES STRAIT ISLANDER SCIENCE CONTEXTS: Knowledge and use of plants (p. 436)

Aboriginal and Torres Strait Islander Peoples have always harvested plants and applied their traditional knowledge to support sustainability of plant resources.

12.10 SCIENCE IN CONTEXT: Controlling land clearing (p. 438)

Clearance controls can reduce habitat destruction and minimise the risk of reduced biodiversity.



Vuttichai Khattai/Shutterstock.com

Is this a typical plant? What kind of environment does it live in? How do you know?

Plants are a very diverse group of organisms that inhabit a wide variety of environments, from deserts to rainforests, to grassy plains and marine environments. What features might help a plant get enough water, sunlight, carbon dioxide and oxygen, no matter where they are living?

- Can you find out more about what has enabled the spread and success of plants in such a wide variety of climates and conditions?

▲ FIGURE 12.01 Different types of plants are suited to different environments.

#12 DIVE INTO SCIENCE!

At the end of this chapter, you can complete Science in Depth Study #12. You can use the information you learn in this chapter to complete the project.

Assessments

- Prior knowledge quiz
- Chapter review questions
- End-of-chapter test
- Depth study: Research project

Videos

- Science skills in a minute: Questions, predictions and hypotheses (12.6)
- Video activities: Respiration in plants (12.1); Photosynthesis (12.1); Plant transport (12.4); Land clearing (12.10); What is deforestation? (12.10)

Science skills resources

- Science skills in practice: Developing questions, predictions and hypotheses (12.6)
- Extra science investigations: Plant growth (12.1); Seed germination (12.7)

Interactive resources

- Label: Plant systems (12.1); Leaf cross-section (12.5)
- Drag and drop: Plant requirements (12.1); Water transport in plants (12.2)
- Crossword: Plant systems (12.5)



 Nelson MindTap

To access resources above, visit cengage.com.au/nelsonmindtap

12.1 Systems in plants

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

✓ describe the structure and function of plant systems.

GET THINKING

When you eat a salad, it could contain many different plant tissues and organs, including seeds, fruit, leaves, stems, roots and even flowers. How do plant tissues, organs and systems work together in a plant?

Cells, tissues, organs and systems in plants

As we saw in Chapter 7, in a multicellular organism such as a plant, many cells combine to make up one individual. Because of its size, a plant cannot rely on diffusion to transport its requirements to each of its cells. In plants, as in animals, we see a division of labour between different cells. When cells differentiate and become specialised to perform a particular function, they form tissue. Tissues perform important functions that support the life of the plant. These include obtaining energy, distributing materials,

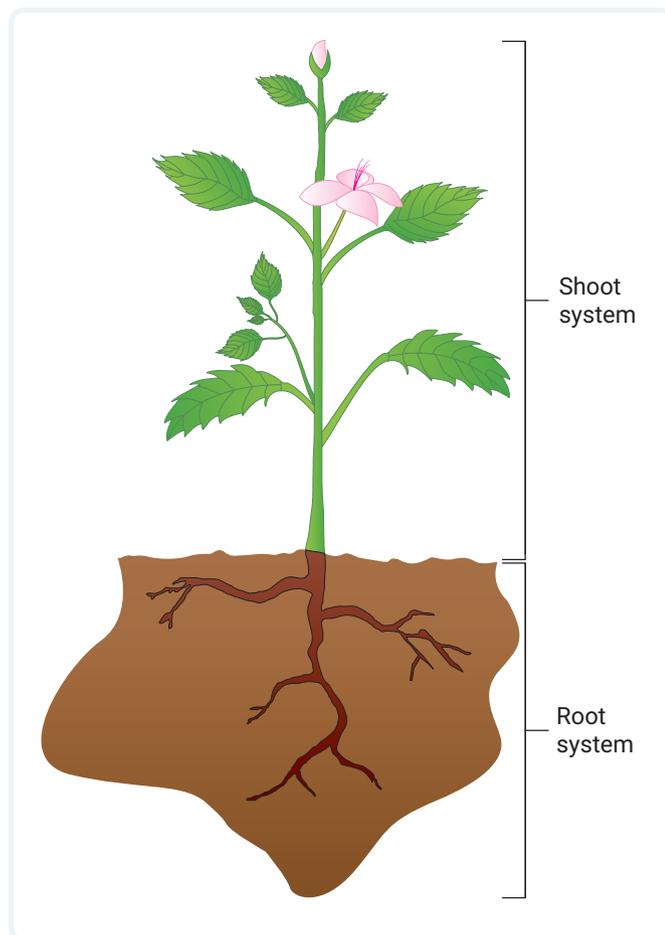
shoot system

the leaves, stems and flowers of a plant; usually above ground

removing waste and exchanging gases. Sometimes different tissues are organised to form an organ, such as a leaf.

In Chapter 11, we looked at some of the important organ systems of animals. Plants do not have all these systems. There are only two organ systems in plants (Figure 12.1.1). These are the:

- shoot system – the stems, leaves and flowers
- root system – all parts of the roots.



Shoot system

The **shoot system** is generally the part of the plant that is above ground. It consists of the leaves, stems and flowers. In trees, the stem is the trunk and all the branches, including the smallest twigs. The stems of some plants are green and can photosynthesise. However, the leaves are the major organs of photosynthesis. In many plants, the leaf consists of a flattened blade and a stalk that attaches the leaf to the stem. The stem supports and spaces out the leaves, to ensure they have good access to sunlight and carbon dioxide.

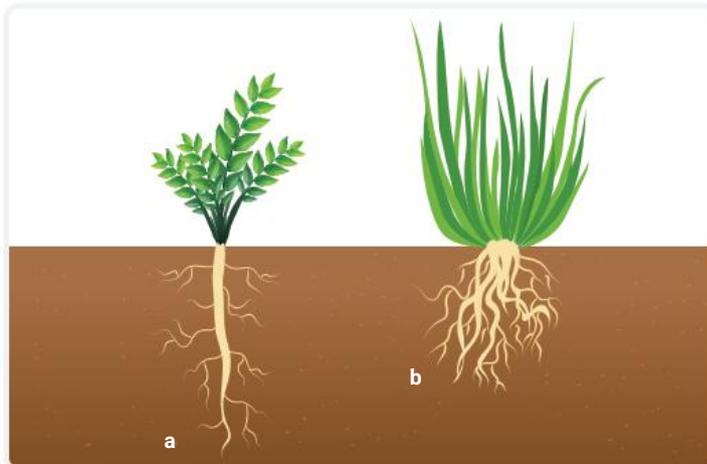
▲ FIGURE 12.1.1 The two organ systems of a plant are the shoot system and the root system.

Root system

The **root system**, consisting of the roots and root hairs, is usually below ground. The root system anchors the plant in the soil, absorbs and transports water and minerals, and stores food. Roots have thousands of hairs just behind their tip. These hairs increase the surface area of the root and allow it to quickly absorb water and nutrients (Figure 12.1.2).

The shape of plant roots varies. Plants with **tap roots** have a large tapering main root with slender side branches. Vegetables such as carrots, turnips and sweet potato have large tap roots, which they use to store food.

Some plants, such as grasses, palms and sugarcane, have **fibrous roots**. These fibrous roots consist of a mat of smaller thread-like roots of similar size. Although fibrous roots do not grow very deep, they hold the soil strongly in place (Figure 12.1.3).



▲ FIGURE 12.1.3 (a) A typical taproot system; (b) a typical fibrous root system



Nigel Cattlin / Alamy Stock Photo

▲ FIGURE 12.1.2 Root hair cells greatly increase the surface area for absorption of water.

root system

the water- and nutrient-absorbing part of a plant; usually below ground

tap root

the large tapering main root of some plants

fibrous roots

many small roots of similar size that grow from the bottom of the stem of some plants

12.1 LEARNING CHECK

- 1 **Name** and **describe** the two systems that make up a plant.
- 2 **State** the functions of the two systems in plants.
- 3 **Compare** tap roots and fibrous roots.
- 4 **Explain** why root hair cells (shown in Figure 12.1.2) are called a tissue.
- 5 Which system in an animal is like the root system in a plant? **Explain** your reasoning.



Video activities
Respiration in plants
Photosynthesis

Interactive resources
Label: Plant systems

Drag and drop: Plant requirements

12.2 Water transport

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

✓ describe the transport of water in plants.

vascular bundle

a combined strand of xylem and phloem tissue in plants

vein

a vascular bundle of xylem and phloem tissue in a leaf

xylem

plant tissue that transports water and minerals from the roots to the rest of the plant

lignin

a material that stiffens and strengthens plant cell walls

GET THINKING

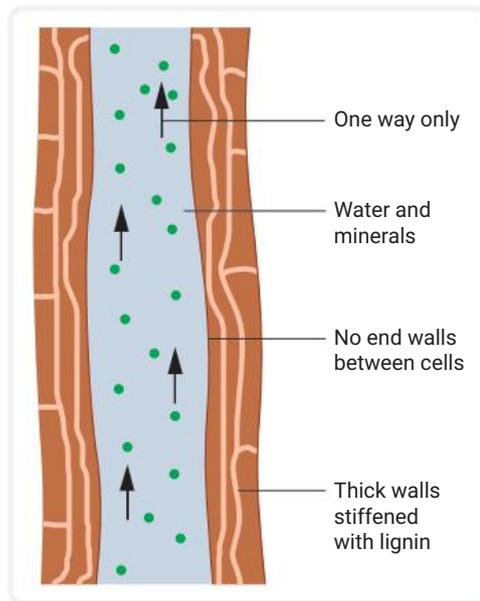
Your heart pumps blood to all your body cells. How is water moved from plant roots to all parts of the shoot without a pump?

Water-conducting tissues

For photosynthesis to occur, the leaves of a plant need maximum exposure to available sunlight, so the best position for a leaf is high above the ground, at the uppermost tip of the stem. Water must travel from the plant's roots to where it is needed in the leaves, and this can be a long way. For example, the tallest gum tree, the Centurion tree in Tasmania, is 100 metres tall.



▲ FIGURE 12.2.1 The branched network of veins in a leaf



▲ FIGURE 12.2.2 Xylem transports water from the roots to the leaves.

Plants transport substances in **vascular bundles**. In the leaves, the vascular bundles are called **veins**. The veins may form a highly branched network (Figure 12.2.1), or they may be parallel, as seen in grass species.

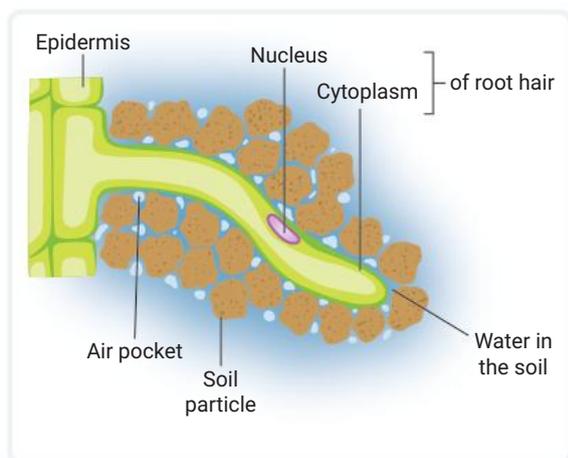
Vascular bundles are made of two types of tissue, xylem and phloem. Phloem transports sugar around the plant – this will be discussed in Module 12.4. **Xylem** carries water from the roots of plants to their leaves. It is composed of groups of long, thin tubes like pipes, made from dead xylem cells with thick walls (Figure 12.2.2).

Lignin is a complex material that makes plant cell walls more rigid. Xylem cells contain lignin, which makes them strong and stiff. Wood is composed almost entirely of xylem, strengthened with lignin, and provides the main support for large plants such as trees.

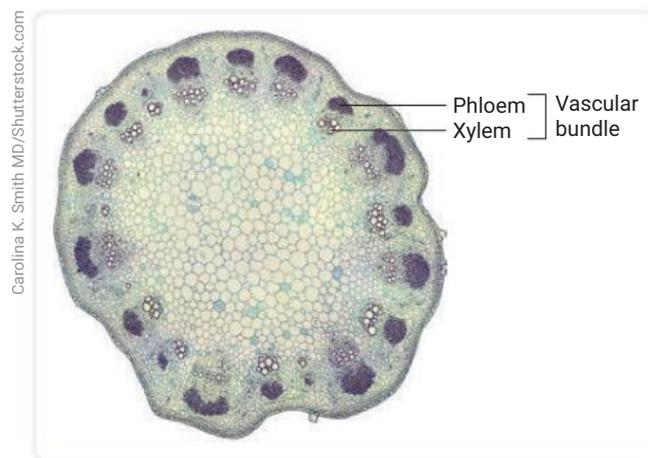
The pathway of water through the plant

Root hairs provide a large surface area that allows plants to absorb water. The root hair cells grow between the soil particles so that they are in close contact with water in the soil. Root hair cells also need to be near air pockets in the soil (Figure 12.2.3). This gives them access to oxygen, one of the substances necessary for cellular respiration, which produces energy. Some of this energy is used to pump minerals into the roots from the soil.

Once inside the root hair, the water moves into the xylem tissue located in the vascular bundle in the root. The water then travels to the rest of the plant.



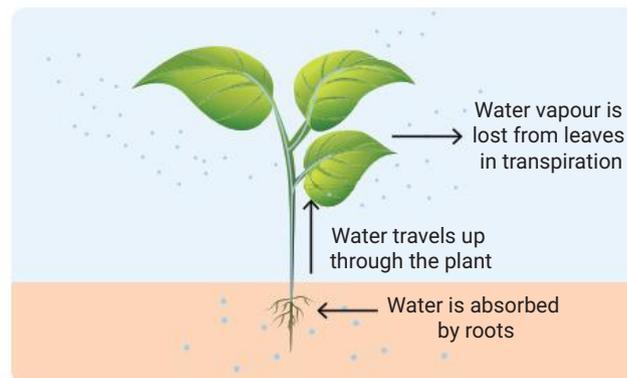
▲ FIGURE 12.2.3 A root hair cell in detail



▲ FIGURE 12.2.4 Internal stem structure, showing the vascular bundles arranged in a circle

In the stem, the vascular bundles are arranged in a circle, with the xylem tissue on the inside (Figure 12.2.4). Every leaf cell is close enough to the vascular bundles of the plant to ensure it has enough water. A continuous column of water runs through the xylem tissue up the stem of the plant to the leaves (Figure 12.2.5). This is quite incredible, because there is no machinery in a plant to pump the water upwards. Water can move like this because of the way its molecules stick together. Water molecules are attracted to each other, so when one molecule moves up, it pulls the other molecules with it. The movement of water upwards in plants is driven by evaporation, mainly from leaves. When water molecules move from the leaves into the air, other water molecules move up the xylem to replace those that were lost. This process is called **transpiration**, and it is how plants can draw water out of the soil and move it all the way up to the highest leaves.

In Chapter 7, you learned how the guard cells on a leaf can prevent water loss by evaporation, by closing the pore between them. In Module 12.5, you will learn more about guard cells.



▲ FIGURE 12.2.5 The movement of water in the xylem from the roots to the leaves

transpiration

the loss of water by evaporation from stomata, mainly from the surface of the leaves

12.2 LEARNING CHECK

- 1 **Define:**
 - a vascular bundle.
 - b vein.
- 2 **Describe** the structure of xylem tissue.
- 3 Why do root cells need oxygen?
- 4 What is transpiration and what is its function?
- 5 **Explain** why the structure of a root hair cell is suited to its function.



Interactive resources
Drag and drop:
Water transport
in plants



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THIS SKILL:

- ▶ making observations to describe and trace the transport of water in a plant.

DESCRIBING WATER TRANSPORT IN A PLANT

AIM

To trace the path of water through a celery stalk to the leaves

MATERIALS AND EQUIPMENT

- fresh celery stalk that has been standing in a beaker of water and red dye for a few hours
- single-edge razor blade
- microscope glass slides and coverslips
- dropper bottle containing water
- tile or cutting board
- microscope

Safety

The razor blade, microscope glass slides and coverslips are sharp. Take care as you handle them. If you cut yourself, tell your teacher immediately. Carry the microscope with two hands and always use it on a level surface.

PROCEDURE

- 1 Write your own question related to the aim.
- 2 Remove the celery from the dye solution and examine the stalk and leaves carefully. Try to observe the path the dye has taken up the stalk and into the leaves. Draw a labelled diagram to show this.

- 3 On the tile or cutting board, cut thin sections across the stalk with the razor blade. Place the thinnest section on the microscope slide with a drop of water and cover it with a coverslip.
- 4 Examine the sections under low magnification and draw a diagram showing the distribution of red colour.
- 5 If you have time and another piece of celery, cut vertically up the stalk about halfway, and immerse one side of the stalk in red dye and the other in blue dye. Repeat steps 2–4.

ANALYSIS

- 1 Describe how the dye is distributed in the stalk. Is the dye found in certain places or is it throughout the stalk?
- 2 What (if any) details could you see using the microscope that you could not see without it?
- 3 Identify the plant tissue in which the dye travelled up the stalk.
- 4 Describe the process by which the dye moved from the water in the beaker to the leaves.

CONCLUSION

Write a conclusion linked to the aim of this investigation. Did you answer the question you asked at the beginning?

12.4 Sugar transport

12.4

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

✓ describe how plants transport sugar from the leaves to other parts of the plant.

GET THINKING

In Module 12.2, you learned how water moves from the roots of plants to the leaves. How do you think sugar is transported around the plant?



Video activity
Plant transport

The function of phloem

Not all of the glucose produced by photosynthesis is used by leaf cells for cellular respiration. Some of the glucose is converted to **sucrose**, which is what we know as sugar. **Phloem** is the tissue responsible for transporting sucrose to other parts of the plant. As we saw in Module 12.2, phloem, together with xylem, occurs in the vascular bundles.

Phloem sap is very different from the watery sap in the xylem. High concentrations of sucrose make the phloem sap thick and syrupy (sugary!). The sap may also contain minerals and plant hormones.

Phloem carries sucrose from the leaves to any part of the plant where it is needed, either for immediate use or for storage. Roots, shoot tips, stems, flowers and fruit all need sugar in order to grow. Any extra sucrose is carried to the root system of the plant, where it is converted into starch for long-term storage.

The structure of phloem

Phloem cells, called **sieve tube cells**, are tubular, like xylem cells. They do not contain a nucleus. Their end walls are perforated by holes to form **sieve plates** (so called because they look like a sieve). Sugar moves from one sieve tube cell to the next through the sieve plates. Unlike xylem tissue, phloem tissue is made of living cells (Figure 12.4.1).

sucrose

the form of sugar transported in the phloem of a plant

phloem

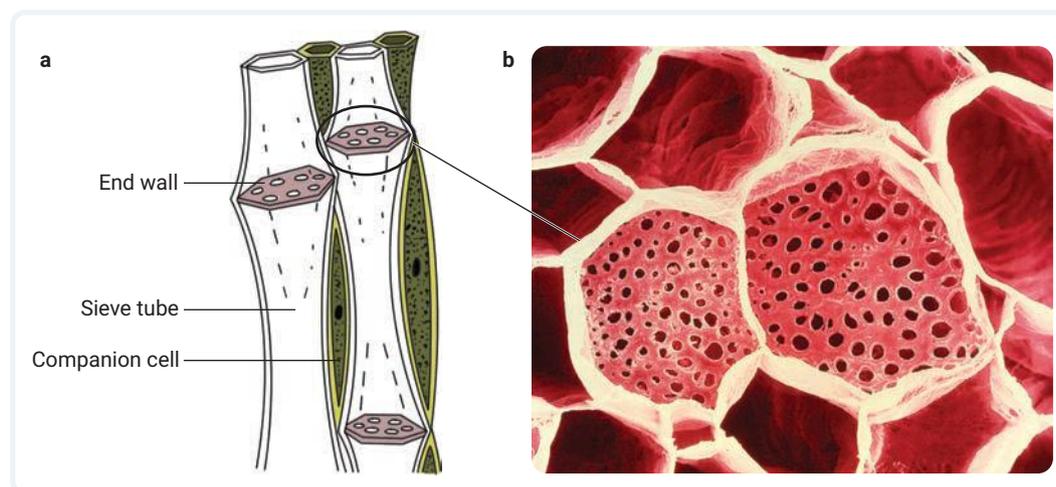
plant tissue that transports sucrose from the leaves to the rest of the plant

sieve tube cell

a nutrient-conducting cell in a plant that forms phloem

sieve plate

holes at each end of a sieve tube cell that allow the passage of sucrose



J.C. REVY, ISM/Science Photo Library

▲ FIGURE 12.4.1 (a) Sieve tube cells and companion cells; (b) a sieve plate, seen from above

companion cell

in plants, a cell adjacent to a sieve tube cell that makes substances the sieve tube cell cannot make

ring barking

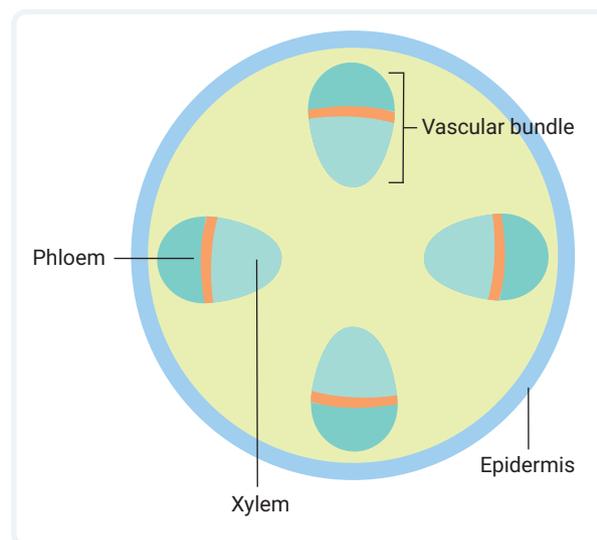
removing the bark containing phloem from around the trunk of a tree, but leaving the xylem intact

Transport in the phloem tissue is very specific. One sieve tube in a vascular bundle may carry sap in one direction, while another sieve tube in the same vascular bundle may carry sap in the opposite direction. Sieve tube cells are closely associated with adjacent **companion cells**. Companion cells contain a nucleus and carry out functions that the sieve tube cell cannot. Without its companion cell, the sieve tube cell would die.

Ring barking

Ring barking is the removal of bark, which contains the phloem, from around the entire circumference of the main trunk of a tree. This may happen through accidental damage, grazing by animals or sometimes insect attack. Sometimes people do this intentionally to kill the tree.

Because the phloem is on the outside of the vascular tissue (Figure 12.4.2), ring barking stops the movement of sugar through the phloem. Since the xylem is undamaged, water and minerals uptake and transport continues unchanged. At first, there is enough stored starch in the roots to maintain cellular respiration and root growth. However, over time these reserves are used up and the tree often dies.



▲ **FIGURE 12.4.2** Diagram of a cross-section of a plant stem showing phloem on the outside

12.4 LEARNING CHECK

- 1 Describe** the difference between xylem sap and phloem sap.
- 2 Name** the cells that are responsible for keeping sieve tube cells alive.
- 3 State** the function of phloem tissue.
- 4 Explain** why sucrose (a sugar) is transported to the fruit of a plant.
- 5 Explain** why a ring-barked tree will often die slowly, rather than immediately.
- 6 State** two reasons why sugar, produced in the leaves by photosynthesis, is transported to plant root cells.

12.5 Control of gases

12.5

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe how gas is exchanged between plants and the air
- ✓ explain how plants control water loss from their leaves.

GET THINKING

You are breathing air in and out from your surrounding environment. Plants are living organisms like you. But unlike you, they do not have lungs and they produce oxygen. How do you think plants move gases in and out of their systems? How does gas go in and out through their leaves?

epidermis

the cellular surface layer of a plant

cuticle

the waxy protective layer on the surface of a plant

stomata

pores in the epidermis of leaves and some stems that control gas exchange (singular: stoma)

Tissues of the leaf

The leaf is the main site of photosynthesis. Although leaves vary in size and shape, they are generally flat and thin. The **epidermis** is a single layer of cells on the upper and lower surface of the leaf. The cells in the epidermis are tightly packed to help prevent water loss from the leaf and protect the plant from attack by bacteria and fungi. The epidermis is covered by a waxy layer, called the **cuticle**, which also reduces water loss (Figure 12.5.1).

The main leaf tissue is between the upper and lower epidermis. At the top of the leaf the cells are brick-shaped and fairly closely packed. Below them are loosely arranged, irregular cells, which contain many chloroplasts. There are many air spaces between the cells.



Interactive resources

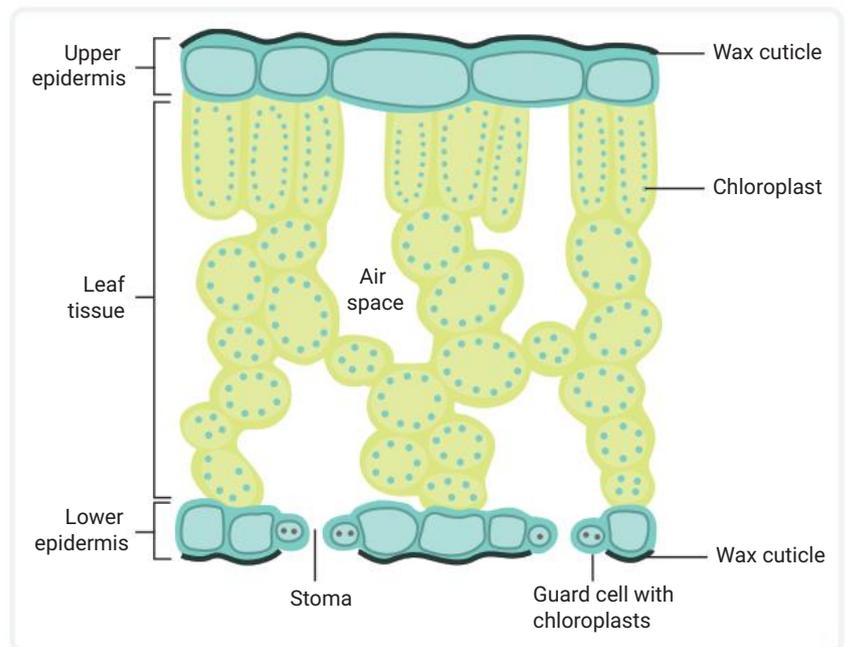
Label: Leaf cross-section

Crossword: Plant systems

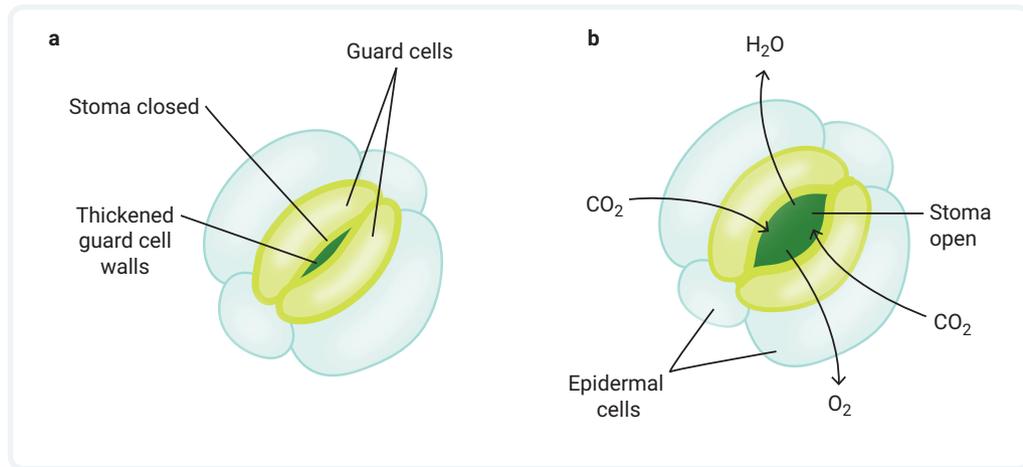
Gas exchange in the leaf

When the leaf is photosynthesising, it takes in carbon dioxide and produces oxygen. These gases enter and exit the leaf through openings in the epidermis called **stomata** (singular: stoma). There are usually more stomata on the lower surface of the leaf – where they are protected from the heat of the Sun – than on the top surface.

The air spaces within the leaf are large near the stomata. This arrangement allows the carbon dioxide that enters the leaf through the stomata to diffuse freely to all of the leaf cells. It also allows oxygen to easily diffuse from the cells where it is produced by photosynthesis through the stomata to the outside. The rate at which gases enter and leave the leaf varies, depending on the needs of the plant.



▲ **FIGURE 12.5.1** Cross-section of a typical leaf. Chloroplasts are shown as green dots inside most of the leaf cells.



▲ FIGURE 12.5.2 (a) Stoma closed; (b) stoma open: carbon dioxide can enter the leaf; water vapour (water in gas form) and oxygen escape

Science Photo Library / Alamy Stock Photo



▲ FIGURE 12.5.3 A surface view of a leaf showing stomata: one closed and one open

Guard cells are pairs of crescent-shaped cells that surround each stoma. When the guard cells absorb water, they swell. This has the effect of opening the stoma. When the guard cells lose water, they flop, causing the stoma to close (Figure 12.5.2). Although the opening and closing of stomata can be affected by several factors, stomata are usually open during the day and closed at night (Figure 12.5.3). Guard cells are the only cells in the epidermal layer to contain chloroplasts.

Movement of water through the leaf

The vascular bundles of the stem link up with those in the leaf. In Module 12.2, you saw that xylem in the vascular bundles

carries water to the leaf, ensuring a ready supply to keep the inside of the leaf moist. During hot weather, a plant may lose water through transpiration from its leaves faster than the xylem can supply it. High water loss causes a plant to **wilt**, where it becomes floppy and droopy. This is where the ability of plants to open and close their stomata is important. As a plant experiences high water loss and wilting, the guard cells also lose water, causing the stomata to close. This reduces further water loss. With enough water, a wilted plant may recover.

guard cells

paired cells that surround the stomata of a plant, allowing them to open and close

wilt

to become limp and to droop through loss of water

12.5 LEARNING CHECK

- 1 **State** the functions of the following structures or actions.
 a Epidermis b Stomata c Cuticle d Wilting
- 2 **State** the function of guard cells.
- 3 **Describe** the process of gas exchange between the air and a plant.
- 4 **Explain** the function of air spaces in the lower part of a leaf.
- 5 **Predict** what would happen to a plant if it was unable to close its stomata.



Developing questions, predictions and hypotheses

SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ developing questions, predictions and hypotheses
- ▶ describing factors affecting stomatal density.

Consider the following steps when planning your investigation.

- ▶ Pose a question
 - The research question describes the purpose of your investigation. What question should you ask to achieve the purpose of your investigation? A question must be able to be investigated.
 - An example is: Does temperature affect the rate of photosynthesis?
- ▶ Make a prediction
 - A prediction is a statement about what you think will happen regarding your question or your investigation. This prediction should be based on your scientific knowledge and not just a guess.
 - An example is: High temperatures will increase the rate of photosynthesis.
- ▶ Develop a hypothesis
 - The hypothesis is an educated guess, based on what you already know or have observed. Your hypothesis should be simple and specific. It is a statement that predicts the effect of changing the independent variable (such as temperature) on the dependent variable (the rate of photosynthesis). To make it a fair test, you need to keep all other variables the same. You cannot prove a hypothesis. Your results might support or disprove your hypothesis.
 - An example is: If the temperature is increased, then the rate of photosynthesis will increase.

INVESTIGATING FACTORS AFFECTING STOMATAL DENSITY

AIM

To compare stomatal density on different plants or different parts of a plant

PART A: LEARNING HOW TO COUNT STOMATA

MATERIALS AND EQUIPMENT

- plant leaf
- fine forceps
- clear nail polish
- microscope
- microscope slide

Safety

Carry the microscope with two hands and always use it on a level surface.

The glass slides are sharp. Take care when using them. Report any breakages to your teacher immediately.



Video

Science skills in a minute: Questions, predictions and hypotheses

Science skills resource

Science skills in practice: Developing questions, predictions and hypotheses

PROCEDURE

- 1 Paint an area of approximately 5 mm × 10 mm on the underside of the leaf with the nail polish.
- 2 Once it is fully dried and set, peel it off using fine forceps and place it on the microscope slide.
- 3 Examine it under the microscope using 100× magnification.
- 4 Count the number of stomata in the field of view. Record your count.
- 5 Move the slide to a different area of the sample and count the number of stomata again. Record your count.
- 6 Repeat Step 5.

ANALYSIS

- 1 Compare the number of stomata in your three different areas.
- 2 Comment on the consistency of your results.

PART B: DESIGN YOUR OWN INVESTIGATION

Investigate the density of stomata on leaves using one of the following:

- different parts of the same plant
- different plants of the same species in different environments
- species with adaptations to limit water loss.

Start by writing a question and developing a hypothesis. Write how you plan to conduct the investigation and identify the variables that need to be controlled. Predict what your results will show.

12.7 Specialised plant structures

12.7

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

✓ give examples of adaptations of plants to different environmental conditions.

GET THINKING

Think of some examples of plants that you know can live in extreme environments. How do they live there successfully? How are they different from other plants?



Quiz
Specialised plant structures

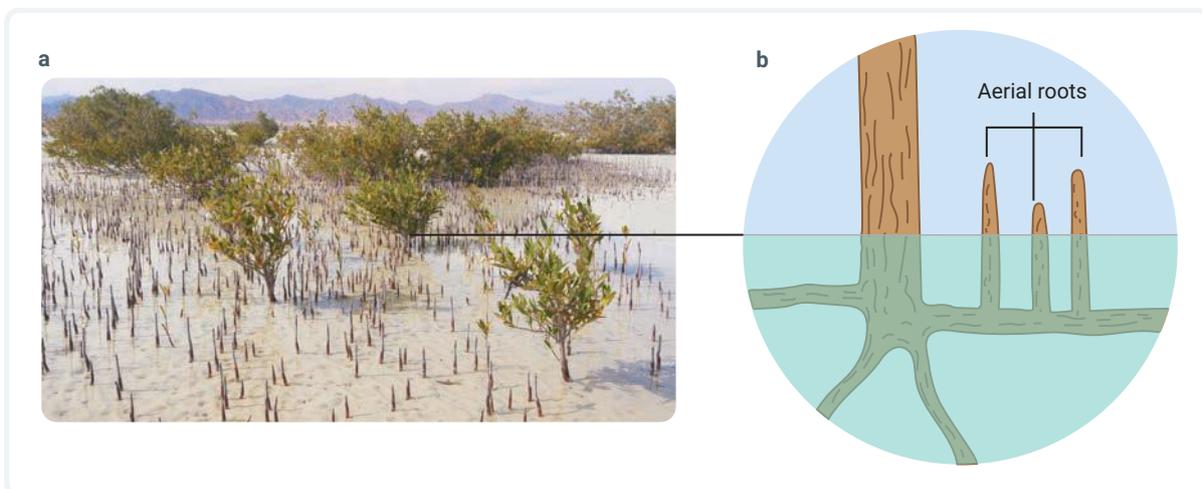
Living in water

A problem faced by underwater aquatic plants is that there is less carbon dioxide and oxygen in water than in air. Therefore, an important adaptation of aquatic plants is that they are not covered by a waxy cuticle. This means gas exchange occurs directly between their photosynthetic cells and the water.

Mangroves live in waterlogged soils of coastal wetland **estuaries**. They are the only trees that thrive in these areas because of their ability to survive in both salt and fresh water. When they absorb water, their roots can block some of the salt and they excrete highly saline water from specialised salt glands in the epidermis of their leaves.

estuary
an area where a freshwater river meets the ocean

Mangroves solve the problem of a lack of oxygen by having aerial roots, called peg roots, that link with underground roots. Numerous pores on the surface of the peg roots allow gaseous exchange even when the main parts of the roots are submerged at high tide (Figure 12.7.1).

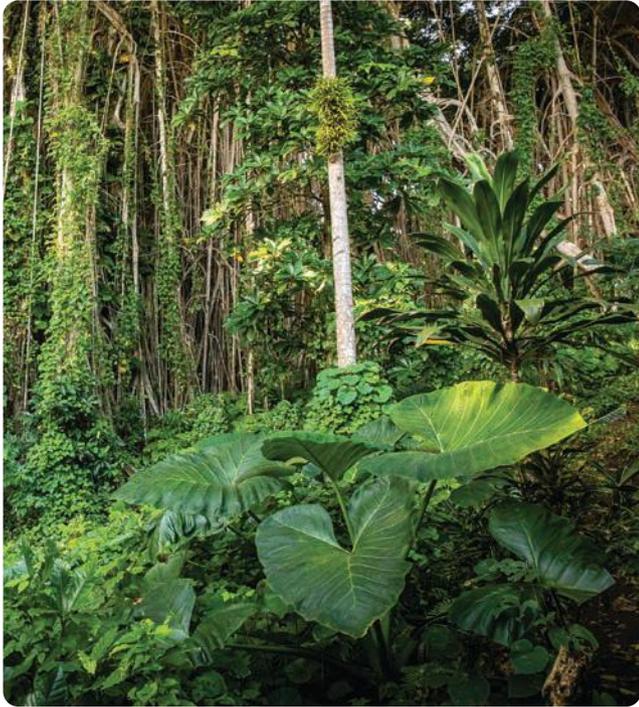


▲ FIGURE 12.7.1 (a) Mangroves and their aerial roots; (b) aerial roots link to underwater roots that have less access to oxygen

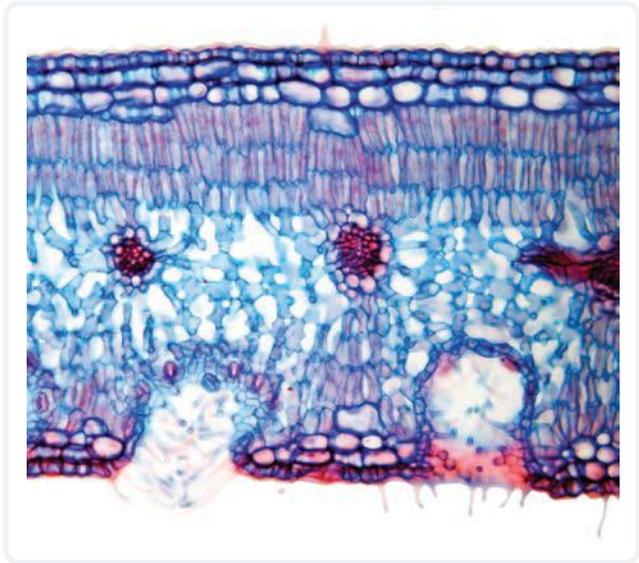
Rainforest plants

Rainforests have a thick, almost continuous, tree **canopy**. It is made up of the overlapping leaves and branches of all the tall trees. The conditions of low light levels and still, moist air beneath the canopy are very different from those outside the rainforest. Plants growing on the floor of the forest usually have very large, flat, dark green leaves (Figure 12.7.2). This type of adaptation increases the surface area available for light absorption in the dim conditions.

canopy
the 'top' of a forest, made up of overlapping leaves and branches of tall trees



▲ **FIGURE 12.7.2** Plants growing below the canopy in a rainforest often have large, flat leaves.



▲ **FIGURE 12.7.3** A microscopic cross-section of a plant leaf showing adaptations to a hot dry environment: a thick waxy cuticle, multiple layers of epidermal cells and 'sunken' stomata

The top 15–20 centimetres of soil on the rainforest floor is decaying leaves, wood and other organic matter. Rainforest plants generally have shallow roots to tap into this rich pool of nutrients.

Plants in hot, dry environments

For plants where water is readily available, such as in a rainforest, the opening and closing of stomata is enough to maintain water balance. But many plants live in hot, dry places where they must reduce their water loss in other ways. High daytime temperatures, combined with low humidity (water in the air), cause water to evaporate through the leaf's epidermis and cuticle, and consequently increase the rate of transpiration. Often, there is little water in the soil to replace this loss. Some plants that live in areas of low rainfall and extreme temperatures have a variety of adaptations to help them survive.

Leaf size and type

In contrast to the large-leaved plants in rainforests, plants in hot, dry climates often have small leaves. Small leaves mean less surface area and fewer stomata to allow water to escape during transpiration. The leaves also have a very thick, waxy cuticle and multiple layers of epidermal cells to reduce water loss from the leaf surface (Figure 12.7.3). Some plants have shiny leaves that reflect heat, or hard, leathery leaves that reduce damage caused by wilting.

Stomata

A number of plant species open their stomata at sunrise and close them in the middle of the day to reduce water loss. They reopen the stomata in the cool of evening. In other species, the stomata may occur in pits on the underside of the leaf; this is known as 'sunken' stomata (Figure 12.7.3). This arrangement reduces water loss, but still allows gas exchange for photosynthesis.

Roots

Many plants in dry areas have long tap roots to reach deep into the soil to access water. Some also have an extensive surface root system to absorb any water present. Aboriginal Peoples have long known how to extract water from these types of roots.

Shortened life cycles

There are plants that cope with drought and high temperatures by not existing during either! These drought-avoiding plants are called **ephemerals**, which is a word meaning ‘lasting for a short time’ (Figure 12.7.4). Ephemerals complete their life cycles quickly and spread large quantities of seeds widely. These seeds can resist heat and drought for long periods, remaining in the soil until rain triggers germination.

Adaptations to fire

Although some plants are killed by bushfires, one benefit of fires for plants is that they open up spaces and create a nutrient-rich seedbed. Many species benefit from fire, including bottlebrushes, hakeas, some acacias and eucalypts. Thin-barked trees rely on their seeds being protected in hard wood capsules, called gum nuts, which are released after the fire has moved through.

Eucalypts have several adaptations that help them recover from fire (Figure 12.7.5). Thick bark protects some species from the extreme heat. High-intensity fires can stimulate buds beneath bark on large branches to begin growing. They appear as bright green, bushy foliage. Some eucalypts have a large swelling at their base, known as a **lignotuber**. The lignotuber holds buds and nutrients, allowing the tree to vigorously re-sprout after fire.



Wikipedia/Mark Marathron (CC BY 4.0)

▲ **FIGURE 12.7.4** An ephemeral in flower in the desert

ephemeral

a plant that completes its life cycle quickly and spreads large quantities of seeds

lignotuber

a partly underground swelling of the trunk of a plant, with many buds that sprout after fire



Photo by David Clode on Unsplash



Daria Nipot/Shutterstock.com



Daria Nipot/Shutterstock.com

▲ **FIGURE 12.7.5** (a) The mountain ash tree. Bushfires readily kill this eucalypt, but before it dies it releases millions of seeds. (b) Leaves sprout from lignotubers at the base of a eucalyptus tree after fire. (c) After damage by fire, buds just below the bark are stimulated to produce shoots.

12.7 LEARNING CHECK

- 1 State** three ways in which plants in hot, dry areas reduce water loss from their leaves.
- 2 Describe** two adaptations of mangrove plants to living in estuaries.
- 3 Explain** the benefit of:
 - a lignotuber.
 - stomata in pits.
 - large, broad leaves in a rainforest.
 - deep tap roots.
- 4 Explain** how ephemerals survive in hot, dry environments.
- 5 Describe** two ways that plants have adapted to fire.



Using a microscope to observe and draw

SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ processing data and information from observations
- ▶ identifying specialised plants structures observed under the microscope
- ▶ drawing and labelling specialised plant structures observed under the microscope.

Observing and drawing from the microscope

Remember to follow these steps when using a microscope.

- 1 Place the microscope on the laboratory bench.
- 2 Move the objective lenses to the lowest magnification 4×.
- 3 Turn on the microscope light.
- 4 Place the slide on the stage of the microscope.
- 5 Focus with the coarse focus knob first, then sharpen focus with the fine focus knob.

Draw from microscope observations

- Draw what you see under the microscope with pencil.
- Draw solid and clear lines.
- Label your drawing using lines, not arrows.
- Indicate the magnification of the drawing.
- Give your drawing a title. This should be descriptive and clearly state what you have drawn; for example, 'A cross-section of a succulent plant leaf'.

SPECIALISED PLANT STRUCTURES UNDER THE MICROSCOPE

AIM

To identify and draw specialised plant structures observed under the microscope

BACKGROUND INFORMATION

A cross-section shows the different horizontal layers of a specimen; for example, if you cut off the top of a carrot. A longitudinal section shows the vertical layers of a specimen; for example, if you cut a carrot lengthways.

MATERIALS AND EQUIPMENT

- light microscope
- microscope specimens of:
 - cross-section of leaf, stem and roots
 - longitudinal section of stem
 - cross-section of mangroves aerial roots
 - cross-section of succulent plant
 - cross-section of leaf showing sunken stomata
(If specimens are not available, use the photographs in Figure 12.8.1)
- microscope slides and cover slips
- pencil
- white paper

PROCEDURE

- 1 Set up a microscope.
- 2 Place on the lowest objective magnification lens (4×).
- 3 Place the slide of the cross-section of a leaf on the microscope stage.
- 4 Focus with the fine knob and then move to the next highest objective magnification lens (10×).
- 5 Carefully observe the organisation of the cells around the vascular bundle (refer to Figure 12.2.4, p. 423, and Figure 12.8.1a).
- 6 Identify the xylem. Usually, the xylem looks like a large, hollow cell in the centre of the vascular bundle.

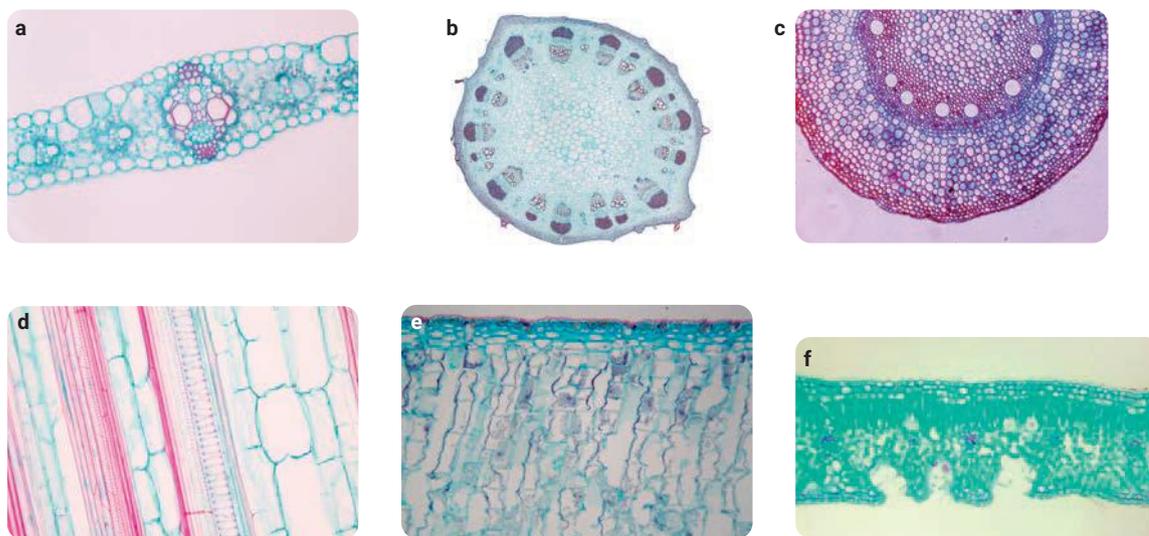
- 7 Identify the phloem. It is a small group of cells that is usually close to the xylem.
- 8 Draw and label what you observe, following the guidance in the Science skills in focus box.
- 9 Repeat steps 2–7 with the slides of cross-sections of stems and roots, referring to Figure 12.8.1b and c.
- 10 Place the longitudinal section of a stem slide.
- 11 Observe the xylem. This is usually seen as hollow tubes and spiral lines (this is the lignin).
- 12 Observe the phloem sieve plates and companion cells. These structures identify the cells as part of the phloem.
- 13 Draw and label what you observe.
- 14 Repeat steps 2–4 for the slides of succulent plants and sunken stomata.
- 15 Draw and label the structures you observe.

ANALYSIS

- 1 What are the differences and similarities between the xylem and phloem cells in the leaf cross-section?
- 2 Discuss why the xylem and phloem cells are near each other.
- 3 Describe the similarities and differences between the leaf, stem and root cross-sections.
- 4 Describe what you observed in the slide from a succulent plant.
- 5 What did you observe about the sunken stomata? Outline the reason for this type of structure in leaves.

CONCLUSION

- 1 What can you conclude about the different cells that you observe in this investigation? Remember to refer to the aim of this investigation.
- 2 What difficulties did you encounter in this investigation?
- 3 How could you improve this investigation?



▲ **FIGURE 12.8.1** Plant structures as seen through the microscope: (a) leaf cross-section, (b) stem cross-section, (c) root cross-section, (d) stem longitudinal section, (e) cactus cells, (f) sunken stomata

12.9 Knowledge and use of plants

**IN THIS MODULE,
YOU WILL:**

- ✓ recognise that Aboriginal and Torres Strait Islander Peoples have successfully and sustainably harvested plant materials for thousands of years
- ✓ examine examples of how Aboriginal and Torres Strait Islander Peoples applied their traditional knowledge to support sustainability of plant resources.

Harvesting plant materials sustainably

Aboriginal and Torres Strait Islander Peoples accumulated a wealth of information and experience concerning the biology, ecology and physical properties of plants over many thousands of years. Although plants form a crucial part of the traditional diet, they were also collected and harvested for many other purposes. As well as being used as a source of medicines and water, plants are important in the construction of tools, weapons, ornaments, musical instruments and toys, and even as an aid to catching animals.

Because plants were essential, Aboriginal and Torres Strait Islander Peoples understood that it was important to harvest plant resources sustainably, so that future generations would still have them.

Harvesting bark

The outer bark of specific types of trees has been carefully harvested by Aboriginal and Torres Strait Islander Peoples for millennia to be used in the construction of canoes, shields, tools, implements and as a canvas for painting or to expose heartwood for carving. To ensure the ongoing survival of the tree, great care was taken not to cause too much damage to the plant's system when the bark was removed. Across southern and eastern Australia, you can still see living, scarred trees. This shows Aboriginal Peoples' in-depth knowledge of plant biology.



▲ **FIGURE 12.9.1** A canoe scar-tree in Yugambeh Country, south-east Queensland. Careful removal of the outer bark to construct a canoe ensures the tree's survival.



▲ **FIGURE 12.9.2** A shield tree that was harvested to make a Kaurna shield, South Australia.



▲ **FIGURE 12.9.3** The bark from trees such as the paperbark can be used to make blankets.

that bears scars believed to be more than 100 years old, and is consistent with the removal of bark to manufacture canoes. The Dyrbal Peoples of the north Queensland rainforest region have long collected bark up to 12 metres above the ground from the banana fig (*Ficus pleurocarpa*) to prevent damage to the root system and ensure survival of the tree. The bark was used to manufacture blankets.

- 1 Use what you have learned about plant systems to **explain**:
 - a which plant system(s) is being affected by the removal of bark.
 - b why the careful removal of bark does not kill the tree.
 - c why a scar forms.

☆ ACTIVITY 1

Sustainable cultivation

Aboriginal and Torres Strait Islander Peoples have long used controlled fires to promote the growth, propagation and germination of certain plants and seeds. This agricultural technique is known as fire-stick farming.

On the Australian mainland, cycads have historically been an important source of carbohydrates for many Peoples. Carefully controlled fires are used to promote the distribution and growth of cycads. In certain areas, discrete groves of cycads are grown and fire is used to improve the quality and yield of crops as well as trigger fruit production when required.

Like the cycads, many other Australian native plants have evolved to become fire tolerant. Some species of acacia and banksia require the heat and/or smoke of a fire to start the germination of seeds. Other species such as eucalypts have developed thick bark that covers the lower sections of their trunks.

Aboriginal and Torres Strait Islander Peoples' knowledge of the adaptations of these plants allowed them to use fire-stick farming to promote growth, distribution and regeneration of these plants.



Joe Sambono

▲ FIGURE 12.9.4 A grove of cycads, Belyuen, Northern Territory

- 1 **Describe** how fire-stick farming is similar to traditional Western farming techniques.
- 2 **a Explain** what adaptations plants need to thrive by fire-stick farming.
b Describe what would happen to plants that don't have these adaptations.
- 3 **Suggest** why controlled low-temperature fires are used by Aboriginal and Torres Strait Islander Peoples when fire-stick farming.

☆ ACTIVITY 2

12.10 Controlling land clearing

BY THE END OF
THIS MODULE, YOU
WILL BE ABLE TO:

✓ describe the role of native vegetation clearance control laws in maintaining biodiversity.

biodiversity

the variety of living species on Earth, including plants, animals, bacteria and fungi



▲ FIGURE 12.10.1 A wildlife corridor linking two areas of natural vegetation



▲ FIGURE 12.10.2 Koalas are being affected by vegetation clearance.

Habitat destruction is pushing some species towards extinction. Since colonisation, large areas of Australia have been cleared for agriculture, grazing and urban development. This has destroyed the habitats of native plants and animals and reduced **biodiversity**.

When people clear the land, they often leave only small, separated areas of natural vegetation. This causes problems because many species rely on being able to move between habitats. Land clearing also threatens native birds, many of which need nesting hollows that occur only in very old trees.

Deep-rooted trees keep the water table levels low, preventing salt in the soil from rising to the surface in water. When such trees are removed and agriculture takes over, the soil becomes more salty. Erosion is also more likely to occur.

In 1983, South Australia introduced laws to control clearing of native vegetation. Despite some early opposition from farmers and graziers, these laws are now considered very important by the community. Most other states now have such laws.

There are many benefits to limiting vegetation clearance.

Photosynthesising plants remove the greenhouse gas carbon dioxide from the air. Linked areas of vegetation, known as wildlife corridors, reduce habitat fragmentation, allowing species to access larger areas (Figure 12.10.1). Protecting native vegetation helps protect endangered animals and rare plants such as orchids.

However, there is more work to be done. The biggest threat to koalas, for example, is habitat destruction (Figure 12.10.2). With rapid human population growth and an increased need for housing, koala habitats are becoming smaller and more fragmented. Satellite images are used to help monitor these areas and detect illegal land clearing.

12.10 LEARNING CHECK

- 1 **Explain** the role of satellite images in protecting biodiversity.
- 2 How does vegetation clearance affect global warming?
- 3 **Describe** the threats facing koalas.



Video activity
Land clearing

What is
deforestation?

12 REVIEW

REMEMBERING

1 **Match** the structure (a–d) to its function (i–iv).

Structure	Function
a Epidermis	i Transports water
b Guard cell	ii Protection; reduces water loss
c Xylem	iii Non-cellular protective layer
d Cuticle	iv Controls opening of stoma

2 **List** four requirements of plants.

3 **Name** the plant tissue that transports sucrose (sugars).

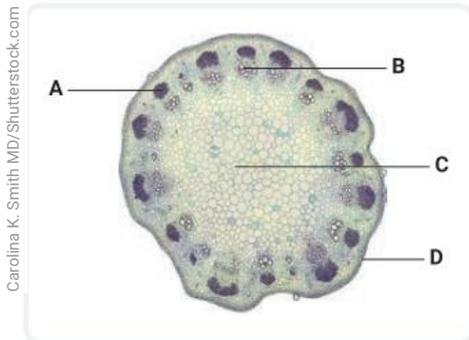
UNDERSTANDING

4 **Explain** three ways in which plants have adapted to recover after a bushfire.

5 **Describe** a specialised structure that allows mangroves to live in estuaries. **Explain** how it functions.

6 The image below is a cross-section of a plant stem. A–D indicate different tissues.

- Name** the type of tissues labelled A and B.
- Which letter is pointing to tissue cells that contain chloroplasts?



Carolina K. Smith MD/Shutterstock.com

APPLYING

7 **a Describe** two examples of traditional sustainable harvesting practices used in Australia.

b Explain how these practices demonstrate sustainability.

8 **Predict** the effect on a plant's water loss if it was sealed in a plastic bag.

9 Grasses are often planted in areas subject to strong winds and high erosion. **Explain** this practice.



10 **Describe** the pathway of a water molecule from the soil, through a plant, to the atmosphere.

11 Rainforest plants often have shallow roots and large, dark leaves. Would you expect these plants to grow well in a desert environment? Give reasons for your answer.

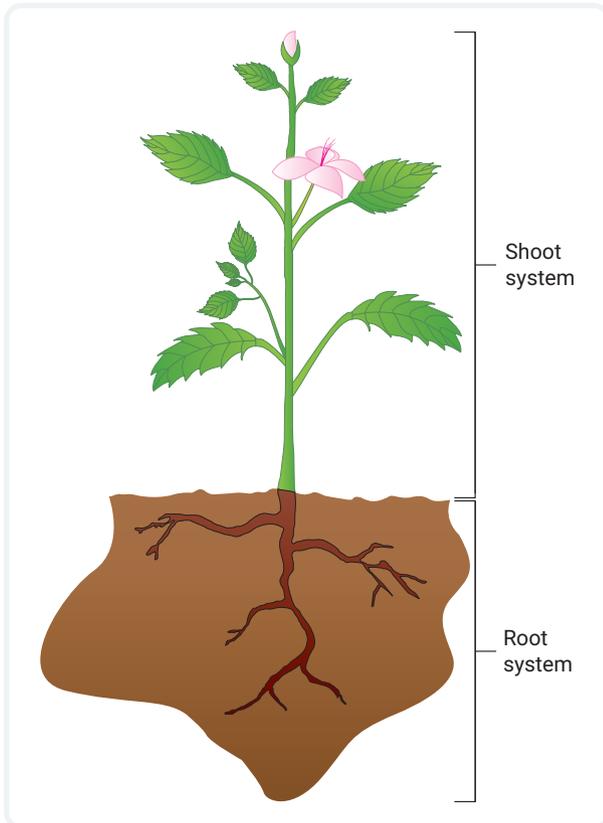
12 **Predict** the effect of blocking the stomata on the rates of photosynthesis and transpiration.

13 How could you decide whether sap from a plant was from the phloem or from the xylem?

14 **Explain** why wildlife corridors are important in conservation.

ANALYSING

- 15 **Compare** and **contrast** the root system and the shoot system of a plant.



- 16 Due to climate change, Australia is having prolonged droughts. **Predict** the effect of those droughts on the rate of transpiration in plants.

- 17 **Analyse** the effect on a plant if part of its phloem is blocked by an insect nest.

- 18 How does xylem differ from phloem in:

- a function?
- b structure?

- 19 **Explain** how the root hair cells of plants and the villi of the small intestine of animals are similar/different.

EVALUATING

- 20 **Explain** the importance of stomata in the transpiration of water.



Science Photo Library/Alamy Stock Photo

- 21 **Explain** two ways that the shoot system and root system work together to ensure a plant's survival.

CREATING

- 22 **Create** a model of a plant that would, in theory, be able to survive the dry, hot conditions on Mars.

SCIENCE IN DEPTH STUDY

#12

1 Connect what you've learned

In this chapter, you've learned a lot about the structure and function of plant tissues and organs, how plants meet their needs and how they interact with their environment. Create a mind map to show how the information that you have learned is connected.

2 Check your thinking

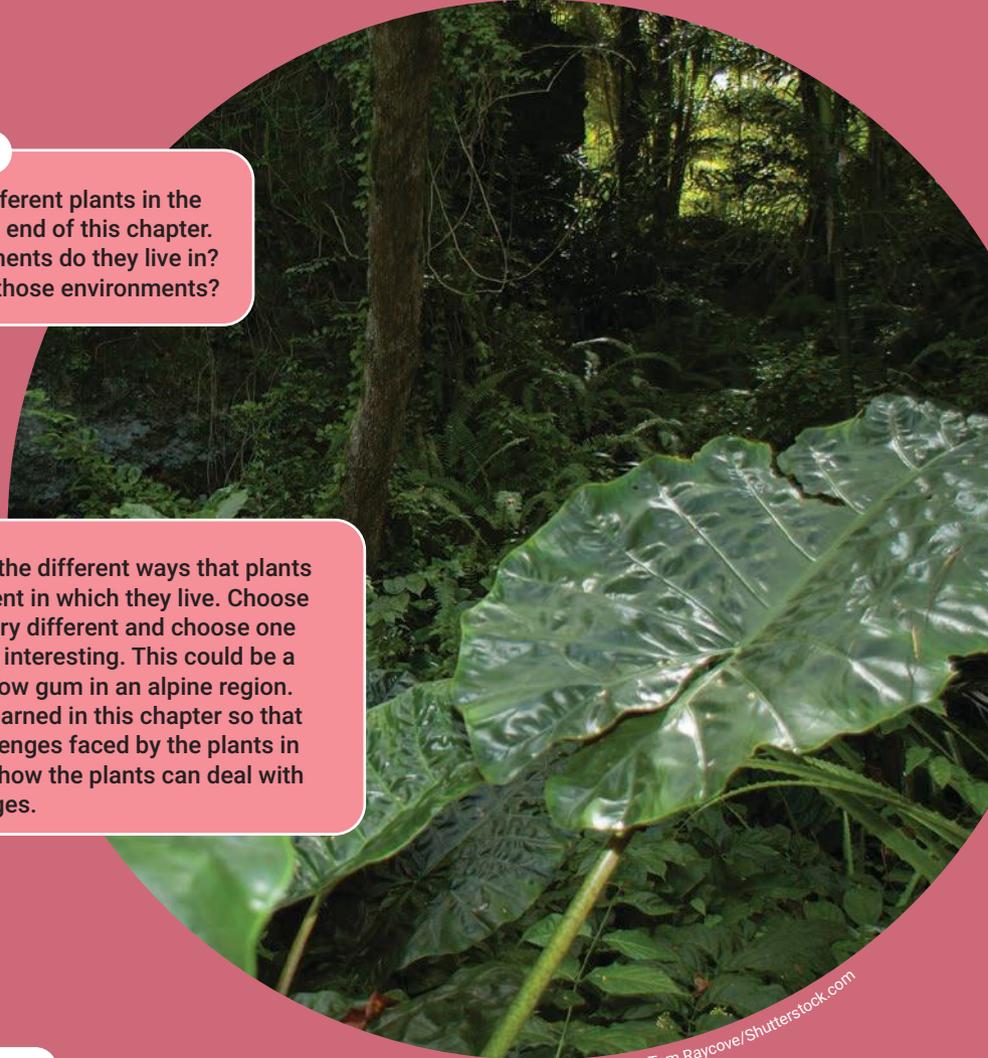
Think about the two different plants in the images at the start and end of this chapter. What types of environments do they live in? How do they deal with those environments?

3 Get into action

Conduct some research into the different ways that plants are adapted to the environment in which they live. Choose two environments that are very different and choose one plant from each that you find interesting. This could be a cactus in the desert and a snow gum in an alpine region. Think about what you have learned in this chapter so that you can understand the challenges faced by the plants in each environment. Compare how the plants can deal with these environmental challenges.

4 Communicate

Use your knowledge, understanding and research to create a 5-minute podcast to communicate your findings to your classmates.



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13

Ecosystems

13.1 What is an ecosystem? (p. 444)

An ecosystem includes the living (biotic) and non-living (abiotic) factors in an environment, and how they interact.

13.2 WORKING SCIENTIFICALLY: **Transect and quadrat skills** (p. 446)

Using transects and quadrats to survey an ecosystem

13.3 Energy in an ecosystem (p. 450)

Photosynthesis and cellular respiration allow energy to enter and leave an ecosystem.

13.4 Reviewing food chains (p. 452)

Food chains model the energy flow from one organism to another.

13.5 Food webs (p. 455)

Food webs visually represent energy flow through an ecosystem.

13.6 WORKING SCIENTIFICALLY: **Modelling food webs** (p. 460)

Modelling food webs for three Australian ecosystems

13.7 Movement of energy and matter in an ecosystem (p. 462)

Matter and energy cycle through an ecosystem.

13.8 Modelling ecosystems (p. 464)

Pyramids can visually represent the biomass, energy or number of organisms in an ecosystem.

13.9 ABORIGINAL AND TORRES STRAIT ISLANDER SCIENCE CONTEXTS: **Traditional ecological knowledge** (p. 467)

Aboriginal and Torres Strait Islander Peoples have a deep understanding of the ecosystems in which they live.

13.10 SCIENCE IN CONTEXT: **Human impact – introduced species** (p. 470)

Changes to an ecosystem, such as introducing a new species, can have a significant impact.

13.11 WORKING SCIENTIFICALLY: **Science communication** (p. 473)

Understanding an environmental issue

KARL HOFMAN/Shutterstock.com



The black summer bushfires in 2019–2020 had a devastating impact on New South Wales communities, wildlife and ecosystems, with over 5.5 million hectares of land burned. Think about the factors that would affect the plants and animals:

- ▶ during the fire
- ▶ immediately after the fire
- ▶ a year after the fire.

Summarise your thoughts in a suitable format, such as a table, mind map or annotated diagram.

▲ **FIGURE 13.01** Bushfires in New South Wales have had a devastating impact on people, plants, animals and many ecosystems.

#13 DIVE INTO SCIENCE!

At the end of this chapter, you can complete Science in Depth Study #13. You can use the information you learn in this chapter to complete the project.

Assessments

- Prior knowledge quiz
- Chapter review questions
- End-of-chapter test
- Depth study: Research project

Videos

- Science skills in a minute: Science communication (13.11)
- Video activities: Biotic factors in ecosystems (13.1); Abiotic factors in ecosystems (13.1); What is an ecosystem? (13.1); Photosynthesis (13.3); Oceanic food chains (13.4); Cane toads (13.10)

Science skills resources

- Science skills in practice: Science communication (13.11)
- Extra science investigations: Light and photosynthesis (13.3); Owl pellets (13.4); Who is in the pond? (13.5)

Interactive resources

- Label: Photosynthesis v cellular respiration (13.3); Biomass pyramid (13.8)
- Drag and drop: Build a food web (13.5)
- Match: Food chains (13.4)

13.1 What is an ecosystem?

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define ecosystem, biotic factor, abiotic factor, community and population
- ✓ describe and explain the interactions in an ecosystem.

GET THINKING

Think about a bird in the garden. Make a list of all the things that may have affected the bird in the last day. Write these in two columns – the things that are living and the things that are non-living. These things, or factors, and how they interact with one another are the ecosystem in which the bird lives.

environment

a unique set of non-living and living factors for a particular area and time

biotic factor

a living component of an ecosystem

population

the organisms of one species that live together in an area

community

all the organisms that live together and interact

abiotic factor

a non-living component of an ecosystem

Environments

An **environment** is the set of conditions within a given area. This includes the:

- living components (**biotic factors**) such as all the plants, animals, bacteria and fungi. These biotic factors include **populations**, each made up of the organisms of one species, which combine to make up the **community** within the environment
- non-living components (**abiotic factors**) such as temperature, amount of light, rainfall, pH of soil and saltiness (salinity) of water.

Australia has many different types of environments (Figure 13.1.1). These range from the hot, humid environments in tropical Queensland to the cold, snowy environments of the Victorian alpine region and the hot, dry environments of Central Australia.



▲ FIGURE 13.1.1 Australia has many different types of ecosystems: (a) Great Barrier Reef, (b) Kakadu National Park, (c) Simpson Desert, (d) Daintree Rainforest, (e) Murray River red gum forest, (f) alpine ecosystem in Tasmania.

Ecosystems

ecosystem

the living and non-living factors of an environment and all their interactions

An **ecosystem** is the biotic (living) and abiotic (non-living) factors, and their interactions, in a certain place. It is slightly different from an environment because it also includes how the factors interact with, or affect, one another.

The sheep in Figure 13.1.2 are part of a paddock ecosystem. Some of the biotic and abiotic factors present in this ecosystem are listed in Table 13.1.1. These factors interact with one another in the ecosystem. For example, the Sun's energy is used by the grass, the sheep eat the grass, the trees provide shade and protection for the sheep, the worms get their nutrition from the sheep manure and the moisture in the soil is used by the trees and grass.

▼ **TABLE 13.1.1** Factors that make up the environment in the paddock

Biotic factors	Abiotic factors
Sheep	Shade from trees
Grass	Light
Trees	Temperature
Flies	pH of soil
Birds	Water in soil
Bacteria in soil	Water in troughs or dams for the sheep
Bacteria in sheep	Humidity
Worms	Wind



iStock.com/Acerebel

▲ **FIGURE 13.1.2** Sheep in a paddock ecosystem

13.1 LEARNING CHECK

- 1 **Define** ecosystem.
- 2 **List** two biotic and two abiotic factors in your classroom environment.
- 3 **Explain** how an ecosystem is different from an environment.
- 4 The photo shows a marine ecosystem.
 - a **List** three biotic factors in this ecosystem.
 - b **List** three abiotic factors in this ecosystem.
 - c **Describe** two interactions that would occur in this ecosystem.
- 5 Different ecosystems can be classified as terrestrial, freshwater or marine. Conduct some research on these types of ecosystems.
 - a **Describe** the key characteristic(s) of each of these types of ecosystems.
 - b Do you think all terrestrial ecosystems are the same? **Discuss** your answer, including evidence for your reasoning.
- 6 Find an area outside, away from buildings, cars and people. Sit quietly and observe the ecosystem.
 - a **List** as many biotic and abiotic factors as you can.
 - b **Describe** five interactions between these factors.
 - c **Model** the ecosystem in a diagram. Use labels and arrows to indicate the factors and interactions.
 - d How do you think the environment is different today from 100 years ago? What do you think caused the change(s)? **Discuss** your answers.



silvae/Shutterstock.com



Video activities
Biotic factors in ecosystems

Abiotic factors in ecosystems

What is an ecosystem?



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ collecting information about the local environment using transect and quadrats
- ▶ collecting information about the abiotic factors of soil acidity and light intensity
- ▶ analysing the distribution and abundance of a species in relation to the abiotic factors.

What are transects and quadrats?

A transect is a path or line of a set length, indicated using a rope or measuring tape. A quadrat is a rigid square frame, usually 1 m² in size.

Why do scientists use transects and quadrats?

Scientists use transects and quadrats to collect data from sample areas in the environment, to understand the interactions between abiotic and biotic factors in an ecosystem.

What do scientists measure with transects and quadrats?

Scientists use transects and quadrats to measure two important things:

- abundance of species: the number of individuals of a species that inhabit an environment
- distribution of species: how a species is dispersed (spread out) across an environment.

How do scientists organise data collected from transects and quadrats?

Scientists record all the data they collect and organise it in tables and graphs for future analysis (see Module 1.10).

In the case of data from environmental studies, scientists use tables to record the numbers of a species around a transect or inside quadrats. This is the key information needed to analyse the distribution and abundance of species.

What is transect and quadrat data used for?

After collecting and organising the data, scientists analyse it to identify trends and patterns related to the species' abundance and distribution in an ecosystem. This data is then used by governments and research organisations to make decisions about the management and conservation of a species and its ecosystem.

USING TRANSECTS AND QUADRATS TO SURVEY AN ECOSYSTEM

AIM

To use a transect and a quadrat to study the distribution of a species in the local environment

MATERIALS AND EQUIPMENT

- a natural space in your local environment
- soil pH kit
- lux meter (or lux meter app)
- clipboard, paper, and pencil for data collection
- calculator

PART A: A TRANSECT

- 10 m tape measure or 10 m string
- 10 icy-pole sticks

PART B: QUADRATS

- 1 m² PVC pipe quadrats

To construct your own quadrats:

- 4 tent pegs
- 40 icy-pole sticks
- large roll of string
- masking tape or blue tape
- metre stick
- 10-metre tape measure

PROCEDURE

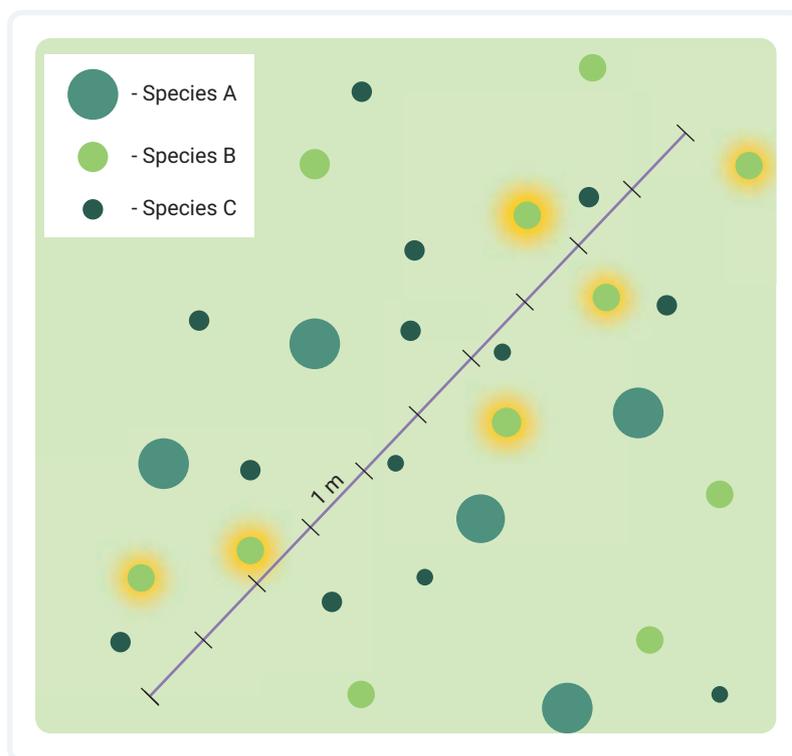
Select a suitable area to conduct your survey; it can be the school oval or a local bushland. You can use transects and quadrats on coastal rock platforms, too.

PART A: A TRANSECT

- 1 Lay the 10-metre tape measure or string across the area of study.
- 2 Mark every metre with an icy-pole stick.
- 3 Choose a species of plant to survey, and count the number of plants of that species that are growing within 10 cm of each side of each marked metre. For example, if you chose species B as shown in Figure 13.2.1, you only count the individual plants shaded in yellow.
- 4 In the case of a rock platform at the beach, choose a species of snail or limpet to count.
- 5 Record the results in a table like Table 13.2.1.

PART B: QUADRATS

- 1 To construct a quadrat:
 - a measure a square 1 m wide
 - b mark each corner stick with an icy-pole stick
 - c join each icy-pole stick with string.
- 2 Randomly place or construct the quadrats around the area of study.
- 3 Choose a plant species to count; this should be the same species you counted in Part A. Once the quadrats are in place, count the number of plants of that species inside each quadrat (Figure 13.2.2). If you want to count more than one species, simply repeat the steps and add extra rows in your results tables.
- 4 Record the details of where you placed the quadrat; for example, note if it is close to a creek or 10 m from a transect line.
- 5 Record the data you collect in a table like Table 13.2.2.
- 6 Repeat steps 2–5 four times for the same species of plant, placing the quadrat randomly each time. At the end of the survey, you will have data for five quadrats.



▲ FIGURE 13.2.1 Diagram of a transect

- 7 To calculate the abundance of the plant species you chose, use this formula:

$$\text{Abundance of a species} = \frac{\text{total number of individuals in all quadrats}}{\text{number of quadrats}} \times \text{area of study}$$

To use the formula, follow these steps.

- a Count the number of plants for your chosen species in the five different quadrats. For example, imagine you counted the following:

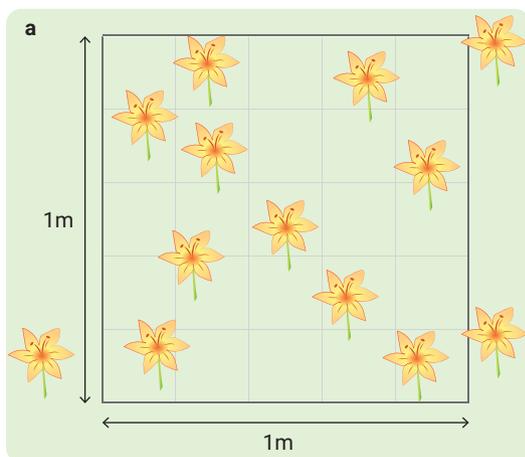
Species	Number of individuals counted				
	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Quadrat 5
Species 1	3	2	1	0	2

- b Add up the total number of individuals you counted for your chosen species; for example, $3 + 2 + 1 + 0 + 2 = 8$.
- c Divide the number of individuals by the total number of quadrats; for example, $\frac{8}{5} = 1.6$.
- d Multiply by the total area size of the study (e.g. school oval); for example, $1.6 \times 1000 \text{ m}^2 = 1600$.

Therefore, in this example, the species you've studied has an estimated abundance of 1600 individuals in the area studied.

PART C: SOIL ACIDITY

- 1 Follow the instructions in the soil pH kit to measure the acidity.
- 2 Measure the acidity of the soil at every metre marked on the transect and in three random spots within the quadrats. Find the average of your three measurements.
- 3 Record the soil acidity in the same results tables.



ephoto corp/Alamy Stock Photo

▲ FIGURE 13.2.2 (a) The design of a quadrat; (b) a quadrat being used in the field

PART D: LIGHT INTENSITY

- 1 Read the instructions on how to use the lux meter (or the lux meter app) to measure the light intensity. Lux is the unit of light intensity.
- 2 Measure light intensity at each metre marked on the transect and in the middle of each quadrat.

RESULTS

Record your results in tables like Tables 13.2.1 and 13.2.2 shown below.

ANALYSIS

- 1 Is there a pattern in the distribution of the species across the transect?
- 2 Is this pattern related to the abiotic factors of light and soil acidity?

- 3 How does the abundance of the plants change across the area based on the quadrats?
- 4 How have the abiotic factors of light intensity and soil acidity affected the distribution and abundance of the species in study?

CONCLUSION

Write a conclusion about the local distribution and abundance of the species that you studied. Refer to the aim of this investigation and the analysis questions.

▼ TABLE 13.2.1 Number of species across a 10 m transect in 1 m intervals

Distance along the transect (m)	1	2	3	4	5	6	7	8	9	10	Total number of plants
Number of species 1 (name the plant)											
Soil pH											
Light intensity (lux)											

▼ TABLE 13.2.2 Number of species in the quadrats

Quadrat number	1	2	3	4	5	Total number of plants
Position details of the quadrat						
Number of species 1 (name the plant)						
Soil acidity						
Light intensity (lux)						

DATA SCIENCE

Learn more about collecting data in **Module 2.6**.

13.3 Energy in an ecosystem

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ model photosynthesis and cellular respiration with word equations
- ✓ explain the role of photosynthesis and cellular respiration in an ecosystem.



Video activity
Photosynthesis

Interactive resource
Label:
Photosynthesis v
cellular respiration

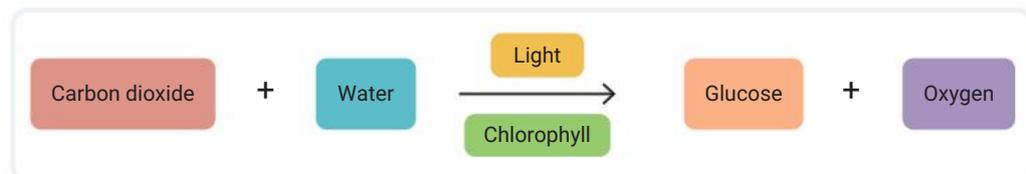
Extra science
investigation
Light and
photosynthesis

GET THINKING

Skim read this module, paying particular attention to the word equations for photosynthesis and cellular respiration. How do you think these processes allow energy to enter and move through an ecosystem?

Photosynthesis

The energy source for all ecosystems is the Sun. As you learned in Chapter 7, plants contain a green pigment called **chlorophyll** that can absorb the Sun's energy and use it in a series of chemical reactions that produce sugars such as glucose. This process is called **photosynthesis**, and it is summarised in the word equation in Figure 13.3.1.

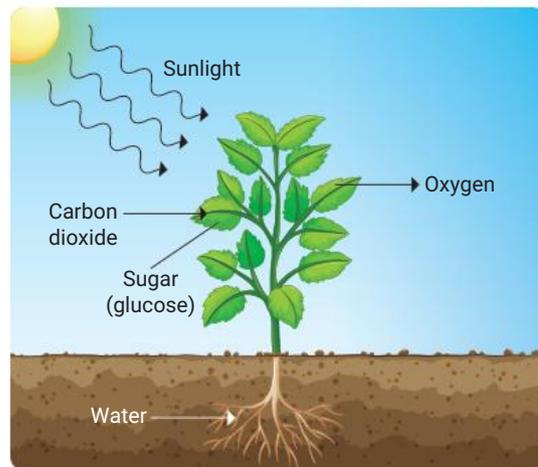


▲ FIGURE 13.3.1 The word equation for photosynthesis

During photosynthesis, plants use light energy from the Sun to convert carbon dioxide and water into oxygen and simple sugars such as glucose (Figures 13.3.2 and 13.3.3). The light energy is now stored as chemical energy in the sugar molecules. Because plants can produce their own sugar in this way, they are called autotrophs. When other organisms eat plants, they consume this energy-rich sugar. Organisms that get their energy from consuming other organisms are known as heterotrophs.



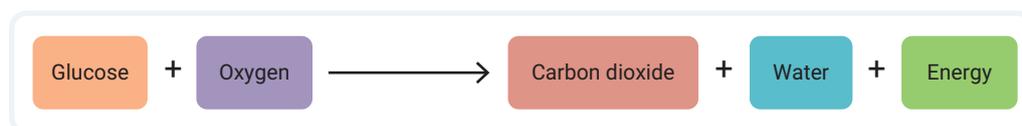
▲ FIGURE 13.3.2 Plants transform the Sun's energy into chemical energy during photosynthesis.



▲ FIGURE 13.3.3 The process of photosynthesis: plants take in carbon dioxide from the air and water from the soil and use light energy to produce sugars and oxygen.

Cellular respiration

As you learned in Module 7.5, the energy stored in sugars can be released during a process called **cellular respiration**. As the name implies, cellular respiration occurs in all living cells, including those of plants and animals. During cellular respiration, sugar (e.g. glucose) and oxygen are converted to carbon dioxide and water, releasing the stored chemical energy. This energy can be used for any active process, including growth, movement, digestion, healing and thinking.



▲ FIGURE 13.3.4 The word equation for cellular respiration

Plants use some of the sugars they produce during photosynthesis in cellular respiration. The rest remains in the plant as a store of energy. When an animal eats the plant, the energy stored in the sugars is available to the animal. That animal will use some of the energy and store the rest. If this animal is then eaten by another animal, the stored energy will be available to the animal that eats it.



▲ FIGURE 13.3.5 The horse and rider use energy released from cellular respiration.

13.3 LEARNING CHECK

- Write the word equation for:
 - photosynthesis.
 - cellular respiration.
- Copy and **complete** the table below by placing a tick (yes) or cross (no) to indicate whether the organism uses each process.

Process	Plants	Animals
Cellular respiration		
Photosynthesis		

- Compare photosynthesis and cellular respiration by listing two similarities and two differences.
- The roots of the word respiration are 're', meaning again, and 'spirare', meaning 'to breathe'. Therefore, respiration means 'to breathe again'. This term is applied to the act of breathing because we are taking oxygen in and carbon dioxide out of our body. **Discuss** how this also applies to the term 'cellular respiration'.
- Do you think it would be possible for an ecosystem to survive without any light? **Discuss** the reason for your answer.

13.4 Reviewing food chains

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ apply appropriate terminology to describe organisms within a food chain
- ✓ explain the role of different organisms within a food chain
- ✓ model the flow of energy and matter in an ecosystem with food chains.



Video activity
Oceanic food chains

Interactive resource
Match: Food chains

Extra science investigation
Owl pellets

GET THINKING

In groups of two or three, brainstorm keywords that you remember about food chains from when you learned about them in primary school. Make flashcards, a Kahoot! or a Quizlet with the word and definition. As you work through this module, add new terms to your collections and refine your existing definitions.

Energy flow

In Module 13.3, you learned how:

- energy from the Sun enters an ecosystem via photosynthesis
- light energy is transformed to chemical energy in sugars
- chemical energy passes from one organism to another when it is eaten.

This passing of energy from one organism to another allows energy to flow through an ecosystem. A **food chain** represents this flow of energy. Because the energy is contained in the food, and food is made of matter, a food chain also represents the flow of matter.

In a food chain, the organisms are listed in order, starting with the plant because this is where the energy enters the ecosystem and the food is produced. An arrow between the organisms shows the flow of energy and matter. The arrow points towards the next organism, indicating that the energy and matter are transferred into this organism. This is illustrated in a simple food chain in Figure 13.4.1.



▲ FIGURE 13.4.1 A food chain

food chain

a single linear diagram that shows the way energy and matter are transferred from producer to consumers

producer

an organism that produces its own food; usually a plant; an autotroph

consumer

an organism that must consume its food; an animal; a heterotroph

primary consumer (first-order consumer)

an organism that eats a producer; a herbivore or omnivore

herbivore

an organism that feeds solely on plants; a primary consumer

secondary consumer (second-order consumer)

an organism that eats a primary consumer; a carnivore or omnivore

carnivore

an organism that feeds solely on animals; a meat-eater

tertiary consumer (third-order consumer)

an organism that eats a secondary consumer; a carnivore or omnivore

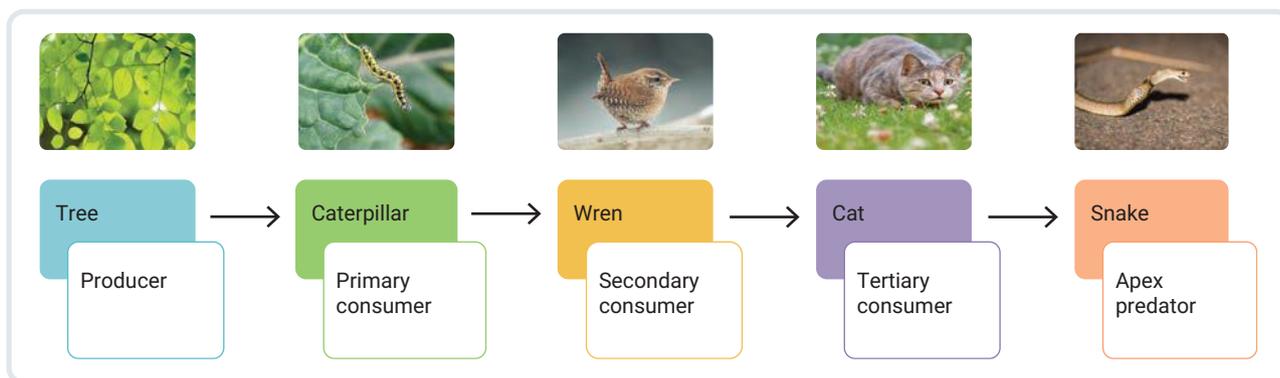
Roles in a food chain

Each organism plays an important role in a food chain (Figure 13.4.2).

A **producer** makes its own food using light energy from the Sun, bringing energy into an ecosystem. This is why the producers are at the start of a food chain. In most cases, the producer is a plant. Algae, a protist, is an example of a producer that is not a plant.

Consumers eat their food to gain energy and, therefore, are animals. They may be a:

- **primary consumer** (or **first-order consumer**) that eats the producer. Primary consumers are **herbivores** because they eat plants
- **secondary consumer** (or **second-order consumer**) that eats the primary consumer. Secondary consumers are **carnivores** because they eat meat. They may also be omnivores
- **tertiary consumer** (or **third-order consumer**) that eats the secondary consumer, making it a carnivore or omnivore.



▲ FIGURE 13.4.2 Classification of the organisms in a food chain

The **apex predator** is the last consumer and the last organism in the food chain. Therefore, it is at the top of the food chain.

apex predator
the organism at the top of a food chain

Some animals, called **omnivores**, eat plants and animals. Humans are omnivores because we can eat some plants, such as lettuce, but we can also eat meat, such as beef. Omnivores are primary consumers in food chains when they eat plants. They are higher-order (secondary or tertiary) consumers in food chains when they eat animals.

omnivore
an organism that eats both plants and animals

Trophic levels

Another way of classifying organisms in a food chain is by their **trophic levels**. A trophic level is the position in the food chain.

trophic level
a level or position in a food chain

- Producers make up the first trophic level.
- Primary consumers make up the second trophic level.
- Secondary consumers make up the third trophic level.
- Tertiary consumers make up the fourth trophic level.

Constructing a food chain

☆ ACTIVITY

The following table gives names, photos and information about organisms in a food chain.

Photos and names				
Honey eater	Wedge-tailed eagle	Bee	Silver princess	Butcherbird
				
Descriptions				
A medium-sized black-and-white bird with a dark, hooked tip to its beak that it uses to kill its prey, such as small birds	A yellow-and-black insect that eats nectar and pollen	A large bird of prey that swoops down and carries its food away	A native Australian bird that eats nectar, insects and berries	A eucalyptus tree with large red flowers in autumn and winter



Procedure

- 1 Match the description for each organism with the name and photo.
- 2 Use the descriptions to construct a food chain for the organisms.
- 3 Identify the:
 - a producer.
 - b first-order consumer.
 - c apex predator.
 - d secondary consumer.
 - e second trophic level.

13.4 LEARNING CHECK

- 1 What types of food do each of the following eat?
 - a Carnivore
 - b Omnivore
 - c Herbivore
- 2 **Match** each term with its description.

Secondary consumer	• Makes its own food
Consumer	• Eats the primary consumer
Producer	• The last organism in a food chain
Apex predator	• Must eat its food
Primary consumer	• Eats the secondary consumer
Tertiary consumer	• Eats a producer
- 3 The following food chain is for a farming ecosystem.
Grass → sheep → dingo → eagle
 - a **Name** the producer in the food chain.
 - b What is the apex predator in the food chain?
 - c How many consumers are in the food chain?
 - d What organism is a herbivore in the food chain?
 - e **Name** the secondary consumer in the food chain.
- 4 **Draw** a separate food chain for each of these situations:
 - a algae are producers.
 - b a shark is the apex predator.
 - c there are three consumers.
 - d an aphid is a primary consumer.
 - e there is a cat in the food chain.
- 5 **List** one similarity and one difference between a:
 - a primary and a secondary consumer.
 - b producer and a consumer.
 - c herbivore and an omnivore.
- 6 **Describe** what the arrows in a food chain represent.
- 7 Is it possible for a secondary consumer to be a herbivore? **Explain** your answer.
- 8 Are apex predators always in the fourth trophic level? Use examples to support your answer.
- 9 What organisms, other than plants, can fulfil the role of producer in a food chain? **Explain** your answer.

13.5 Food webs

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ define food web
- ✓ explain how a food web represents the flow of energy and matter through an ecosystem
- ✓ model the flow of energy and matter in an ecosystem with a food web.

GET THINKING

Discuss these questions with a classmate.

- 1 Do you only eat one type of food?
- 2 Do you think organisms are part of only one food chain?
- 3 Why do you think your answers to questions 1 and 2 are important in an ecosystem?



Interactive resource
Drag and drop: Build a food web

Extra science investigation
Who is in the pond?

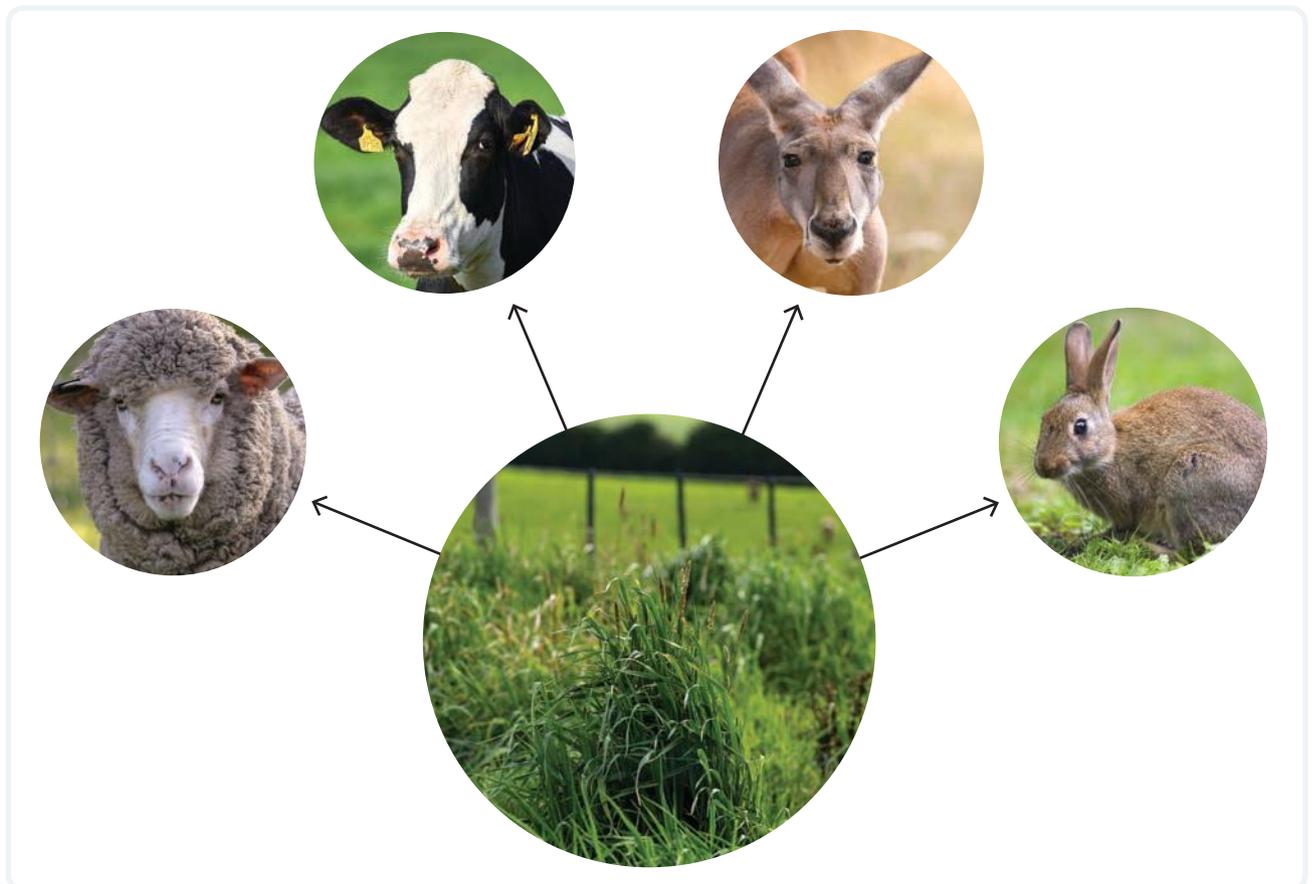
Interconnecting food chains

An ecosystem contains a variety of organisms. Most organisms feed on more than one food source and often organisms are consumed by more than one animal (e.g. Figure 13.5.1). Therefore, there are many interconnecting food chains occurring in each ecosystem.

DATA SCIENCE



Learn more about scientific models in **Module 2.9**.



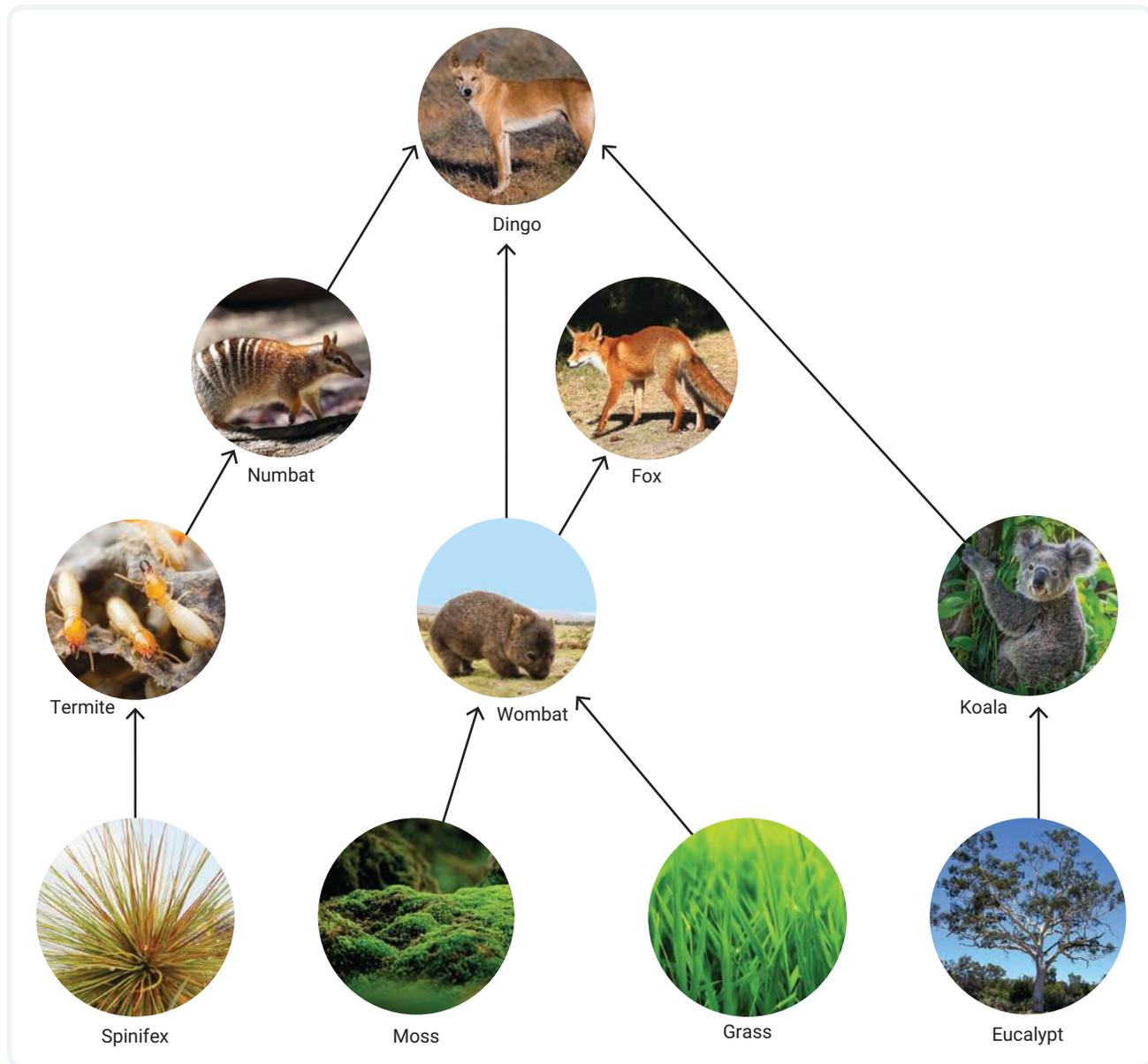
▲ **FIGURE 13.5.1** In a farming ecosystem, grass may be eaten by sheep, cows, kangaroos and rabbits.

food web

a group of interlinked food chains that gives an overall picture of how energy and matter are transferred through an ecosystem

What is a food web?

A **food web** is all the food chains that occur in an ecosystem linked together. It gives a bigger picture of the flow of energy and matter through an ecosystem than a single food chain. Figure 13.5.2 shows an Australian food web.

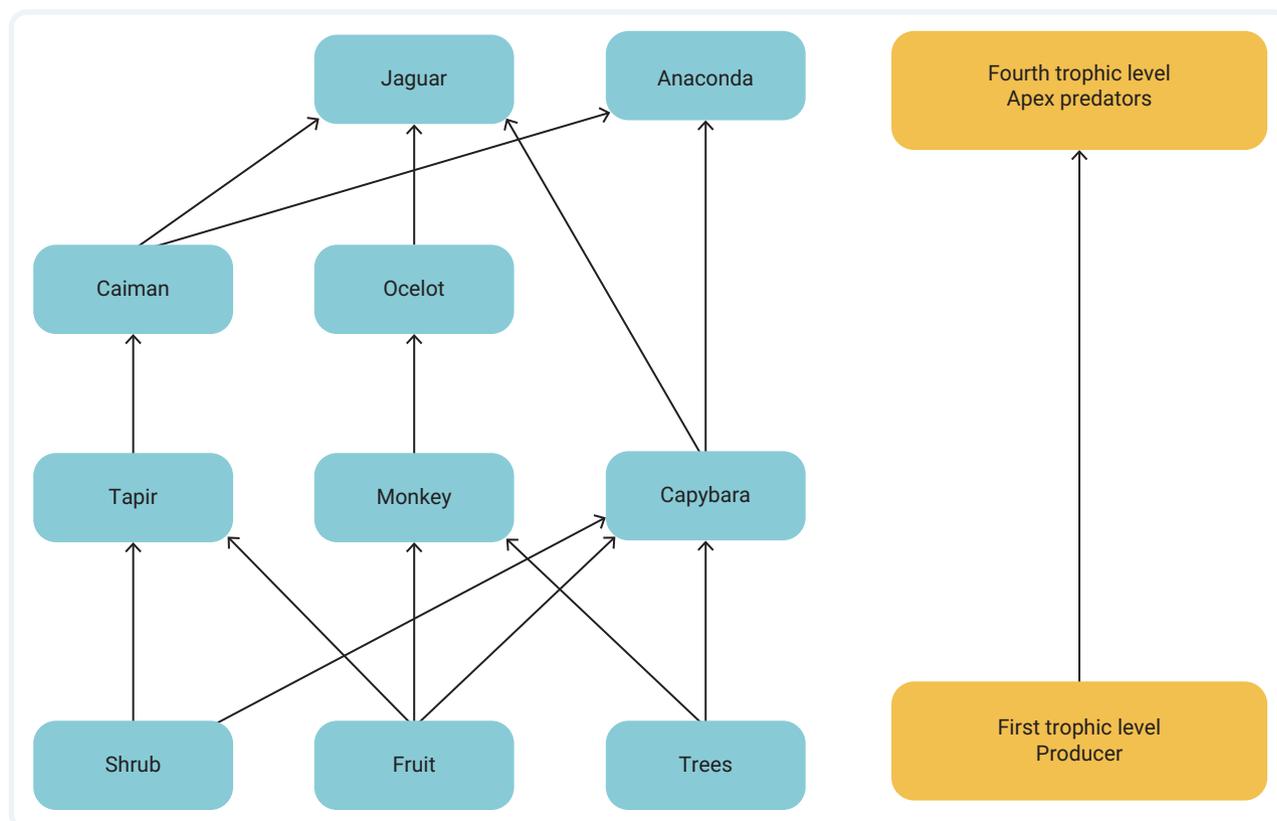


▲ FIGURE 13.5.2 A food web in an Australian ecosystem

Drawing food webs

Remember that a food web is a series of connected food chains. Therefore, we use arrows to show the direction of energy and matter flow.

Organising a food web can make it easier to interpret. Therefore, if possible, organise organisms according to their trophic levels, with the first trophic level at the bottom and the apex predators at the top (Figure 13.5.3).



▲ FIGURE 13.5.3 A food web for an Amazon rainforest ecosystem. Note how the organisms have been arranged according to their trophic levels.

Interpreting food webs

Food webs help scientists predict what could happen if one of the organisms in the food web was disrupted in some way. For example, what might happen if a drought caused most of the grass to die in the food web represented in Figure 13.5.2? The wombat would need to eat more moss to survive. If there wasn't enough moss, then the number of wombats in the ecosystem may decrease. They might move to a new area to find food, or they might die of starvation. If there were fewer wombats, then there would be less food for the foxes to eat, reducing their numbers as well. And the dingoes may need to eat more numbats or koalas, affecting their populations, too.

Creating a food web

Materials and equipment

- pictures of the following organisms with their names



Acacia



Warthog



Lion



Star grass



Hare



Impala



Thompson's gazelle



Red oat grass



Termite



Rüppell's vulture



Wild dog



Aardvark



Wildebeest



Cheetah



Hyena

- large piece of butcher's paper and marking pen, or whiteboard, magnets and whiteboard marker

Procedure

- 1 Arrange the organisms into producers and consumers.
- 2 Place the pictures of the producers at the bottom of the butcher's paper (or whiteboard) to start the food web.
- 3 Table 13.5.1 lists some food chains for a savanna ecosystem. Use food chain A to place the relevant consumers above the producer. Draw arrows to connect the organisms.

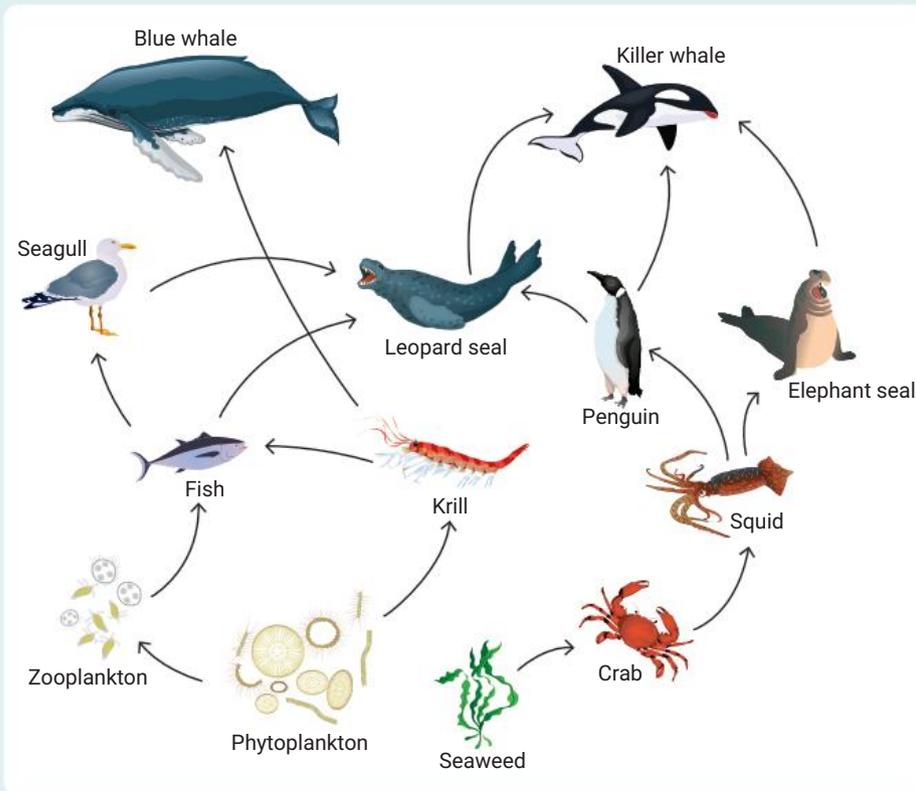
▼ TABLE 13.5.1 Food chains for a savanna ecosystem

A	Red oat grass → warthog → wild dog
B	Acacia → impala → lion
C	Star grass → Thompson's gazelle → Rüppell's vulture
D	Red oat grass → wildebeest → hyena
E	Star grass → hare → lion
F	Star grass → Thompson's gazelle → lion
G	Red oat grass → termite → aardvark → hyena
H	Acacia → impala → cheetah
I	Star grass → warthog → lion
J	Red oat grass → hare → wild dog
K	Star grass → hare → cheetah
L	Red oat grass → wildebeest → lion

- 4 Repeat step 3 for the other food chains B–L to add the remaining consumers.
- Remember to try to keep each trophic level on the same level of the food web.
 - You may need to move the organisms (and their arrows) to make them fit in an organised manner.
- 5 When you have finished, take a photo of your food web or copy it into your notebook.

13.5 LEARNING CHECK

- Define** food web.
- Explain** why a food web gives a more accurate representation of interactions in an ecosystem than a food chain does.
- Use the figure below to answer the following questions.



- Name** two producers in the food web.
 - Name** an apex predator in the food web.
 - Name** a species that exists in more than one trophic level in the food web.
 - Draw** two separate food chains from this food web.
 - Zooplankton and phytoplankton are two organisms in this ecosystem. **Research** the meaning of their names and **explain** their different roles in the ecosystem.
- 4 Choose an ecosystem that you are familiar with. **Create** a food web to represent the flow of energy and matter in that ecosystem.



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ creating a model of a food web
- ▶ describing the advantages and limitations of the model
- ▶ analysing the interactions between the animals and plants in the model of the food web.

In Module 2.9 you learned about physical and mathematical models. In this investigation, you will use food web models to:

- represent interactions between biotic factors in the environment
- represent the flow of energy and matter
- show the effect of pollution in the environment
- show the effect of introducing another species in energy and matter flows.

Benefits of using food web models

Food web models are good at representing complex interactions and processes that can be difficult for us to observe or otherwise explain.

Limitations of food web models

Because food web models simplify complex interactions, they can't show all aspects of a food web. For example, food web models don't show the number of producers or the numbers of animals; instead, they represent only one of each species. Therefore, when we use the model, we must make assumptions, such as there being fewer individual animals and plants as the trophic levels increase towards the apex predator.



Worksheet
Modelling food
webs

MODELLING FOOD WEBS FOR
THREE AUSTRALIAN ECOSYSTEMS

AIM

To model food webs for some Australian ecosystems

MATERIALS AND EQUIPMENT

- ☑ printed A4 size photos for each of the food webs described below (see 'Modelling food webs' worksheet on Nelson MindTap):
 - **Desert:** true grass, blue gum eucalyptus tree, flat-top acacia, princess parrot, koala, blind snake, red kangaroo, emu, greater slick-nest rat, bandy-bandy snake, thorny devil lizard, wedge-tailed eagle and dingo
 - **Murray River estuary:** phytoplankton, macro algae, shrimp, small mud crab, yabby, insect larvae, black swan, Australian herring, flathead gudgeon, yellow-eye mullet, greenback flounder, black bream, Australian salmon, pelican, rail, Australian darter, long-nosed fur seal
 - **Daintree Rainforest:** grass, tree ferns, blue quandong, cauliflory tree, native hibiscus, green tree frog, gecko, golden green stag beetle, mosquito, bandicoot, musky rat kangaroo, golden silk orb weaver, spotted cuscus, butterfly, bat, goanna, sugar gliders, spot-tailed quoll, cassowary, forest dragon, tree snake, koala, tree kangaroo
 - **Introduced species:** feral pigs, cane toad, carp, gold fish, feral cat, camel, sheep
 - **Pollutants or human impacts:** acids in water, acids in soil, deforestation, herbicides, insecticides
- ☑ 3 × 50 m rolls of string or wool

PROCEDURE

- 1 Your teacher will divide the class into three groups.
- 2 Each group takes a set of worksheets with photos for one of the food webs, and one roll of string or wool.
- 3 Cut out the photos in the worksheet.
- 4 Each person collects one or two photographs of each animal or plant in the food web and sits in a circle with their group.
- 5 Identify the producers in the food web.
- 6 Identify the first-order consumers of the producers in the food web.
- 7 In the circle, link the producers with the first-order consumers by using the string, starting from the producer to the first-order consumer.
- 8 Identify the second-order consumers and use the string to link them with the first-order consumers.
- 9 Repeat step 8 until the top predator is linked to the food web. Remember, some animals are going to eat more than one type of plant or animal, and some plants and animals will be eaten by more than one animal.
- 10 Keep the strings tense in your hands. You will now be able to see the large food web your group has created.
- 11 Introduce one new species. Link it to the species that it will eat and the animals that will eat it (if applicable).

- 12 Introduce a pollutant or human impact and link it into the food web. You will need to change some of the other links within the food web. For example, if you introduce a chemical that kills insects, you will need to remove the photos of insects from the food web and the strings that link to the animals that eat insects.

ANALYSIS

- 1 What does the string represent in the food web that you created with your group?
- 2 Were you able to link all the animals and plants in the food web? Which ones have more links than others? Why?
- 3 When you introduced a new species, what happened to the string connections in the food web? Why?
- 4 What happened when you introduced a pollutant or human impact to the food web?
- 5 Discuss the advantages and limitations of this type of food web model.

CONCLUSION

Write a conclusion for this investigation, referring to the aim and the questions in the analysis.

13.7

Movement of energy and matter in an ecosystem

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe the flow of energy in an ecosystem
- ✓ describe the roles of decomposers in an ecosystem
- ✓ explain how matter cycles through an ecosystem
- ✓ compare the movement of energy and matter through an ecosystem.



Quiz
Energy and matter flows

GET THINKING

The movie *Lion King* talks about the 'circle of life'. What do you think this means? Share your thoughts with a partner and discuss this until you come up with an answer that makes sense to both of you.

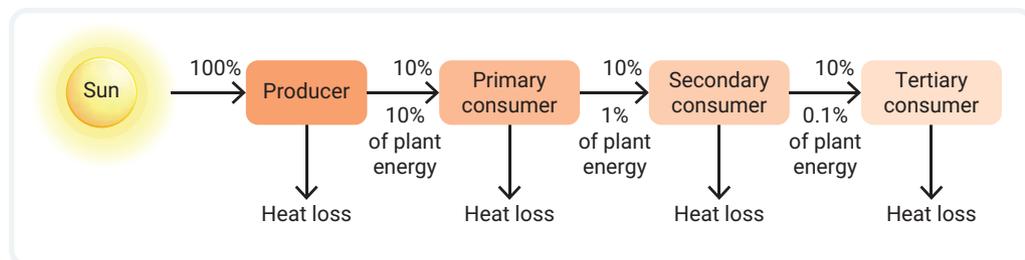
Both energy and matter move through an ecosystem. However, they do this in slightly different ways. Energy flows through the ecosystem, whereas matter cycles through.

Flow of energy

Energy enters an ecosystem via photosynthesis as light energy, which is transformed into the chemical energy in sugars. The producers use some of the chemical energy, some is lost as heat and the rest is stored. This means that, when the plant is eaten, only about 10 per cent of the chemical energy remains to be transferred to the consumer.

A similar loss of energy occurs at each trophic level. When something is eaten, approximately 90 per cent of the energy is either used or lost as heat. This leaves only 10 per cent of the energy available for the next trophic level when the organism is consumed. Therefore, at each trophic level, there is less and less energy available.

Figure 13.7.1 summarises how energy moves through an ecosystem.



▲ **FIGURE 13.7.1** The flow of energy through an ecosystem. Note how only 10 per cent of the energy at each trophic level is transferred to the next level. This means that only 0.1 per cent of the original energy is available to the tertiary consumer.

Energy enters and leaves an ecosystem. Therefore, we describe its movement as a flow rather than a **cycle**.

Cycling of matter

Eventually, all organisms in an ecosystem die. The nutrients and energy from the dead organisms are used by organisms called **decomposers**. Decomposers are organisms, such as bacteria and fungi, that can break down dead organisms into simple nutrients.

cycle

a continuous, connected and repeated process

decomposer

an organism, such as a fungus or bacteria, that breaks down dead matter

Decomposers fulfil an important role in an ecosystem (Figure 13.7.2). When they break down the complex structures in plants and animals, nutrients are released in a form that producers can use. Therefore, matter re-enters the food web, allowing it to be continually recycled in an ecosystem.

You can show decomposers in a food web, usually below the producers. However, because they consume the remains of all organisms, there will be many arrows on the food web, which can make it confusing. Therefore, you can leave the decomposers out of the food web. However, we always assume that they are present.

Decomposers can be classified as **detritivores** or **saprophytes** depending on how they digest the dead matter. Table 13.7.1 summarises the differences between them.



▲ FIGURE 13.7.2 Decomposers such as fungi break down dead organic matter.

▼ TABLE 13.7.1 A comparison of detritivores and saprophytes

	Detritivore	Saprophyte
Method of digestion	Eats dead or decaying matter and then breaks it down	Uses enzymes to break down matter and then absorbs the nutrients
Where matter is broken down	Internally	Externally
Examples	Worms, beetles 	Bacteria, fungi 

detritivore

an organism that feeds on dead or decaying matter

saprophyte

an organism that digests dead matter before ingesting it; also known as a saprotroph

13.7 LEARNING CHECK

1 Define:

- a detritivore.
- b saprophyte.

2 Explain why energy flows through an ecosystem but matter cycles.

3 Create a Venn diagram to show the similarities and differences between the movement of energy and the movement of matter through an ecosystem.

4 Write a short story from the viewpoint of a carbon atom in the body of a living thing and later in carbon dioxide in the air. **Describe** the atom's journey through a food web, and the situations it may find itself in.

5 Do you think it is possible for there to be a very long food chain? **Apply** your understanding of energy flow in an ecosystem to support your answer.

13.8 Modelling ecosystems

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ model the energy, biomass and number of organisms by using pyramids
- ✓ describe, and explain, the shape of energy, biomass and number pyramids.

GET THINKING

Look at the pyramids in this module. Can you predict what they are showing you? Why do you think they look like this? Share your answers with a classmate.

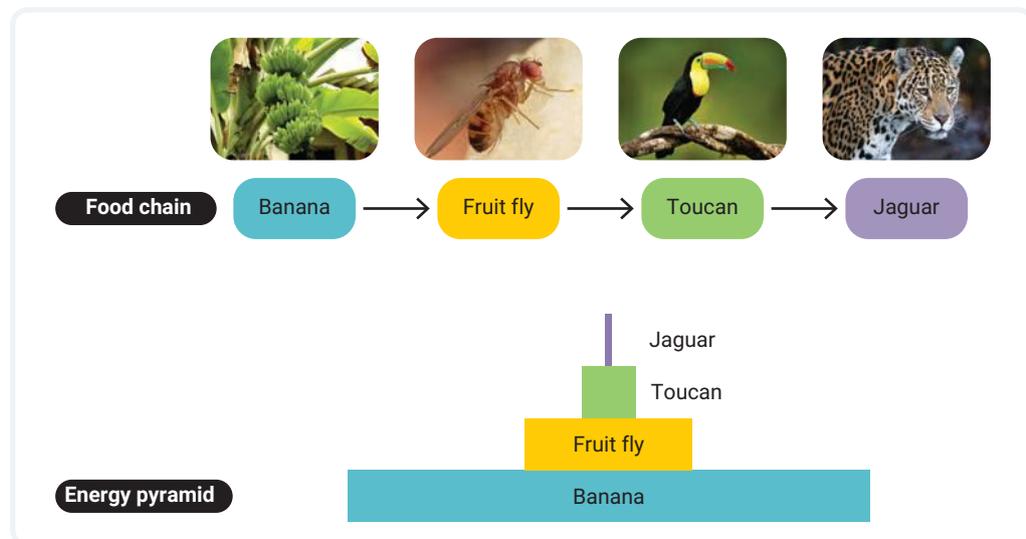
In ecology, information can be organised in different pyramids. Each pyramid is made from a series of bars stacked on top of one another. Each bar reflects the characteristics for a trophic level in a particular food chain, or food web, starting with producers on the bottom. In some pyramids, the edges of the bars are angled to create a smooth, triangular shape.

Energy pyramids

energy pyramid

a graphical representation of the total energy present at each trophic level of an ecosystem

An **energy pyramid** reflects the total energy in each trophic level of a food chain (Figure 13.8.1). As energy is lost at each level, the bars become smaller and smaller, creating an upright pyramid.



▲ FIGURE 13.8.1 An energy pyramid for a food chain in an Amazon rainforest

Biomass pyramids

biomass

the mass of living organisms

Biomass is the mass of living things, including plants, animals and micro-organisms. In an ecosystem, the biomass for each population depends on both the mass and the number of organisms of a species.

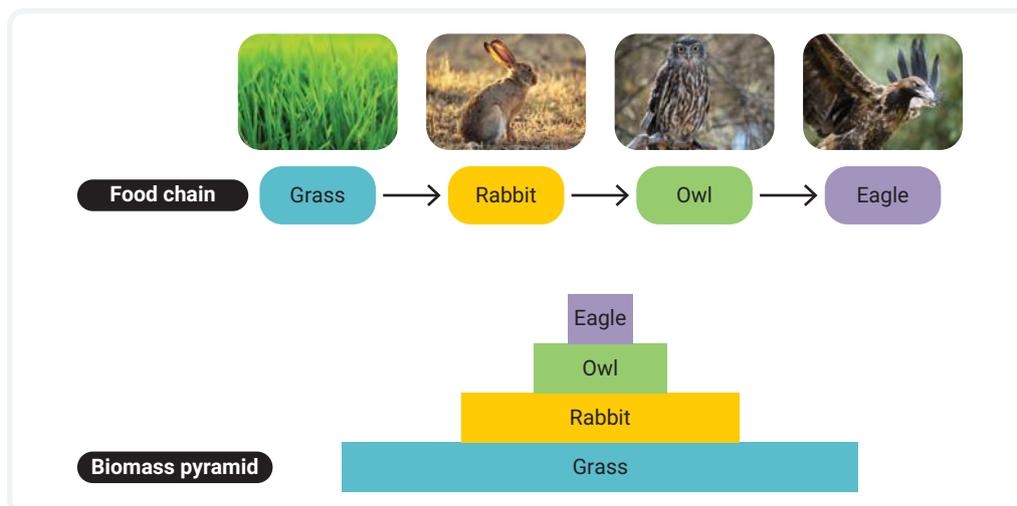
biomass pyramid

a graphical representation of the total biomass present at each trophic level of an ecosystem

A **biomass pyramid** represents the total biomass for each trophic level of a food chain. The length of the bar represents the amount of biomass: the larger the biomass, the longer the bar. The biomass pyramid for a grassland food chain is shown in Figure 13.8.2.



Interactive resource
Label: Biomass pyramid

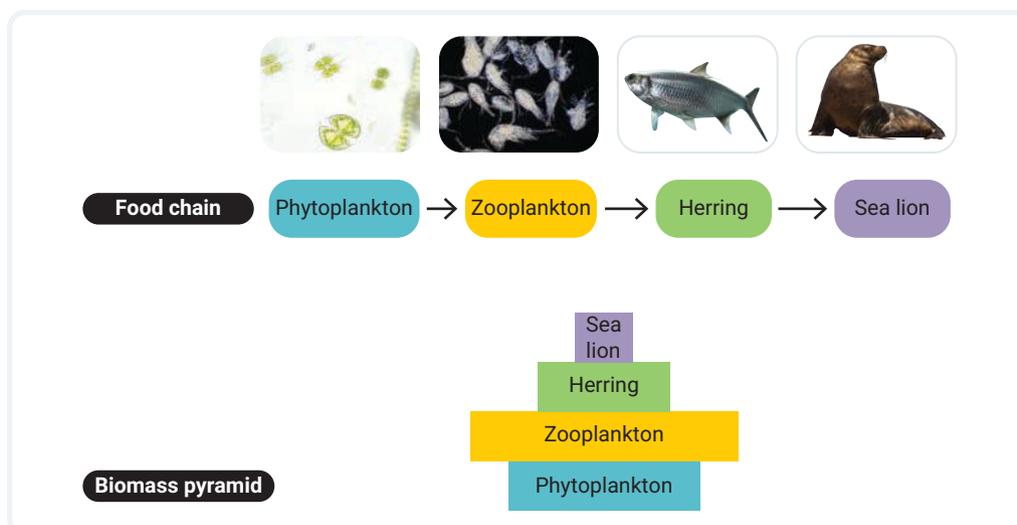


▲ FIGURE 13.8.2 A biomass pyramid for a grassland food chain

In most food chains, the biomass decreases at each trophic level. This is because not all mass is passed onto the next trophic level – it may be lost as waste or may not be consumed.

The exception to this is some marine environments where the pyramid may be inverted, or upside down. This occurs when the organism being eaten reproduces very quickly, replacing the biomass that is lost. For example, **phytoplankton** is a producer that can grow and reproduce very quickly. Therefore, it can provide food for a population of zooplankton that has a larger biomass than the biomass of phytoplankton (Figure 13.8.3).

phytoplankton
microscopic algae; a producer that can support a large biomass of primary consumers

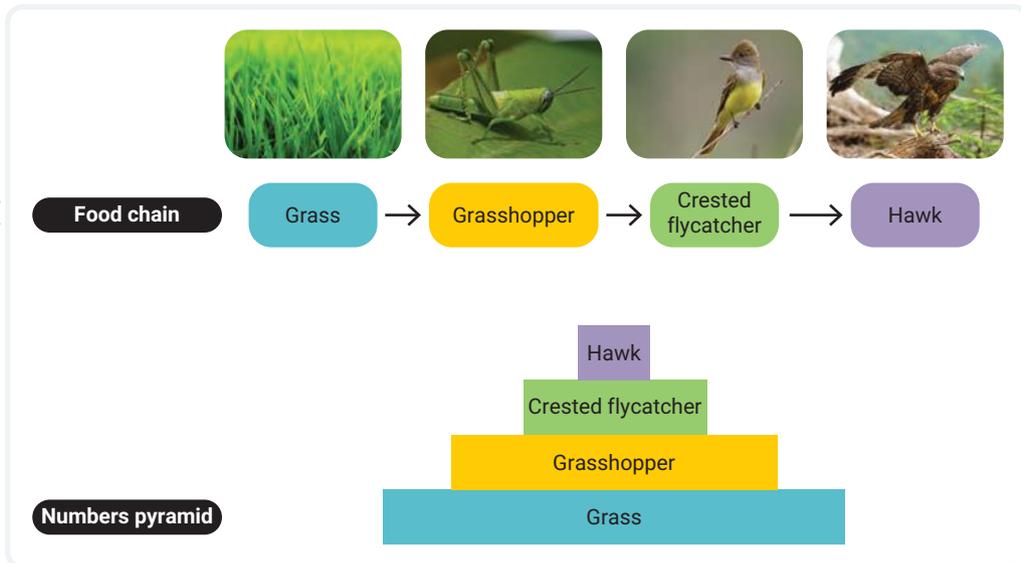


▲ FIGURE 13.8.3 An inverted pyramid for a food chain in a marine environment

Numbers pyramids

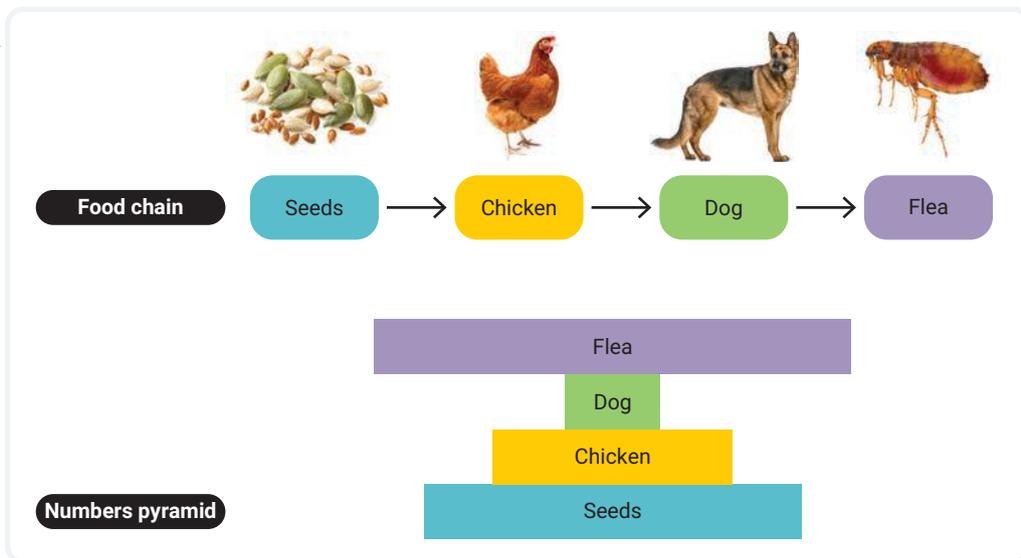
As its name implies, a **numbers pyramid** represents the number of each organism. In most cases, numbers decrease up a food chain, creating an upright pyramid. For example, in the food chain in Figure 13.8.4, one crested flycatcher would need to eat many grasshoppers to survive.

numbers pyramid
a graphical representation of the total number of organisms at each trophic level of an ecosystem



▲ FIGURE 13.8.4 An upright numbers pyramid

However, numbers pyramids can take any shape because the number of organisms is related to their size. For example, lots of seeds can provide food for one chicken, or one dog can provide food for a lot of fleas (Figure 13.8.5).



▲ FIGURE 13.8.5 A numbers pyramid with a different shape

13.8 LEARNING CHECK

- 1 **Explain** why energy pyramids are always upright.
- 2 What type of biomass pyramid may be inverted? **Explain** why.
- 3 **Draw** an energy pyramid for the following food chain.
Grass seed → mouse → owl
- 4 **Create** an energy, biomass and numbers pyramid for the food chain below. Then **write** a paragraph to describe the amount of energy, matter or biomass in each trophic level.
Tree → termite → anteater → jaguar

13.9

Traditional ecological knowledge

**IN THIS MODULE
YOU WILL:**

- ✓ explore Aboriginal and Torres Strait Islander Peoples' traditional ecological knowledge
- ✓ examine the importance of traditional ecological knowledge to restoring ecosystems.

Traditional ecological knowledge

Over many thousands of years, Aboriginal and Torres Strait Islander Peoples have accumulated a deep knowledge of their areas' ecosystems and the natural resources they provide. This is known as traditional ecological knowledge. It is knowledge that has developed through Aboriginal and Torres Strait Islander Peoples' long and sustained contact with their Country/Place, and their experience of living for centuries in close connection with the land.

Seasonal calendars

Aboriginal and Torres Strait Islander Peoples have a deep scientific understanding of the complexities and connections between animals, plants, seasonal, weather, and environmental and astronomical changes. This knowledge has been used to devise highly comprehensive seasonal calendars based on thousands of years of observations. These calendars demonstrate understanding of the connection and interactions among and between living things and their environments.

The diversity of climate and ecological zones across Australia means that the seasonal calendars of different Aboriginal and Torres Strait Islander Peoples are also quite diverse. The names and times of the seasons are defined by localised resources and events. For example, the seasonal calendar of the Miriwoong Peoples, whose Country encompasses the east Kimberley region of Western Australia and extends into the Northern Territory, consists of three seasons. In contrast, the seasonal calendar of the D'harawal Peoples of the region north of Sydney consists of six seasons.

Plant and animal seasonal indicators

In traditional times, these calendars allowed Aboriginal and Torres Strait Islander communities to make accurate predictions about recurring seasonal events such as the availability of particular resources or timing of journeys. For example, the Aboriginal Peoples of D'harawal Country know that the lilly pilly berries start to ripen when they hear the cries of tiger quolls in search of mates. When the lilly pilly berries start to fall, they know it is time to begin their journey to the coast in search of other seasonal resources. The Yawuru Peoples of the Broome region in Western Australia know that it is time to harvest land rather than marine resources by the budding of the bloodwood tree.



Joe Sambono

▲ **FIGURE 13.9.1** Lilly pilly berries. These berries are often associated with significant events within the ecosystem.



▲ **FIGURE 13.9.2** Morning glory clouds over the Gulf of Carpentaria region mark the beginning of the wet season.

Weather seasonal indicators

Annual weather patterns identified by phenomena such as wind strength and direction, appearance of particular cloud type and temperature changes, have long been related to seasonal events. For example, the Yanyuwa Peoples of the Sir Edward Pellow Group of Islands in the Gulf of Carpentaria know that the appearance of ‘morning glory’ clouds (a rare weather phenomenon that occurs at predictable times) indicate the beginning of the wet season. These clouds also indicate the time when seagulls and sea turtles lay their eggs.

Astronomical seasonal indicators

Aboriginal and Torres Strait Islander Peoples’ astronomical knowledge, collected through observation over millennia, connects phenomena in the sky with occurrences and events on Earth. For example, the Kurna Peoples of the Adelaide Plains region in South Australia use the position of the star Parna near the lower left of the Moon to mark the beginning of Parnati (autumn). This is the time when stone fruits are ripe and fish such as whiting are ready for harvesting. The visibility of the constellation Scorpius in the morning sky indicates to the Yirrkala Peoples of east Arnhem Land in the Northern Territory that it is time to trade sea cucumbers.

Integrating seasonal indicators

Around the world, researchers are increasingly recognising and turning to traditional ecological knowledge to provide a more complete understanding of the natural world. The intimate knowledge of seasonal patterns held by Aboriginal and Torres Strait Islander Peoples is based on integrating and organising observations from astronomical and weather events, physical changes in plants and the land as well as the presence, movement and habits of animals.

While the Western calendar is based on specific units of time (days, months and seasons), Aboriginal and Torres Strait Islander Peoples’ calendars are based on cyclical processes in ecosystems – ecological time. Aboriginal and Torres Strait Islander Peoples’ holistic understandings of their Country/Place allows seemingly separate events to be connected. For example, the Narungga Peoples of Yorke Peninsula in South Australia identify the flowering of the billy button (*Craspedia* species) as a signal that marine resources such as the mulloway are plentiful and, prior to colonisation, indicated it was time to move to coastal areas.



▲ **FIGURE 13.9.3** Billy button flowers signal to the Narungga Peoples that mulloway are plentiful so it is time to move to coastal areas.

Recognising traditional ecological knowledge

The importance of including Aboriginal and Torres Strait Islander Peoples and their traditional ecological knowledge and viewpoints in natural resource management is being increasingly recognised.

Aboriginal and Torres Strait Islander Peoples sustainably managed Australian ecosystems for thousands of years prior to colonisation. As a result, learning from them should contribute to more sustainable resource use, conservation of biodiversity and natural ecosystem restoration.

Traditional Owners are increasingly working with scientific and government organisations to inform land management practices and restoration processes in areas where the impact of colonisation and introduced species has damaged environments.



Joe Sambono



Joe Sambono

▲ FIGURE 13.9.4 (a) Cane toads and (b) gamba grass are introduced species that have had significant negative impacts on Australian ecosystems.

- 1 **Explain** what is meant by traditional ecological knowledge.
- 2 **Suggest** why Aboriginal and Torres Strait Islander Peoples have different calendars.
- 3 **Describe** the advantages of using Aboriginal and Torres Strait Islander Peoples' seasonal calendars to understand ecosystems.
- 4 **Propose** why traditional ecological knowledge should be used when assessing and repairing damaged ecosystems.
- 5 **Discuss** how Aboriginal and Torres Strait Islander Peoples' seasonal calendars and traditional ecological knowledge can be used to assess the effect of the changing climate on ecosystems.

☆ ACTIVITY

13.10

Human impact – introduced species

BY THE END OF
THIS MODULE, YOU
WILL BE ABLE TO:

- ✓ define native species, invasive species and endangered species
- ✓ explain how an event affects an ecosystem.

Introduced species in Australia

As humans, we have a responsibility to consider the impact of our actions on the environment. Unfortunately, humans have made changes that have had negative impacts on ecosystems, including climate change, **deforestation**, pollution, poaching and mining.

Another change that can have negative impacts is the introduction of species that are not native to an ecosystem. When Australia was colonised, food plants such as wheat and corn, and animals such as cows, sheep and goats were introduced. To create gardens, roses, blackberry bushes and ivy were planted. Rabbits, foxes and European carp were released into the wild for sport. Unfortunately, there was no understanding of the consequences of these actions on the **native species** of Australia.

These plants and animals are called **introduced species** because they have either arrived accidentally or been deliberately brought to an area. Sometimes the local conditions are not favourable to the introduced species, and it struggles to survive. However, some introduced species thrive in their new environment because they are free from the predators and diseases that kept their numbers in check in their native environment. These species cause harm to their new environment and are termed **invasive species**.

If the new environmental conditions are favourable, introduced species will reproduce quickly, and their population size will increase. As their numbers increase, they compete with native species for food and shelter. This can cause a decrease in the population of native species, which may become **endangered** or even **extinct**.

deforestation

the removal of naturally occurring forest by logging or burning

native species

an organism that originated and developed in the environment

introduced species

a species that was not part of the original ecosystem; for example, plants, animals and micro-organisms brought into Australia from other countries

invasive species

an introduced species that disrupts the ecosystem

endangered

in danger of becoming extinct

extinct

no longer in existence

Controlling introduced species

Overall, the impact of introduced species can be extremely detrimental to a local ecosystem. Tables 13.10.1 and 13.10.2 give examples of deliberate and accidental species introductions to Australia. Perhaps the most well-known example is the rabbit. Rabbits arrived with the First Fleet in 1788 and were kept as pets and as a source of food. However, it was the deliberate introduction in 1859 of rabbits for sport that probably led to a devastating rabbit plague in 1890. The rabbit population reached 600 million before it was partly controlled by the release in 1950 of the myxoma virus, which causes the disease myxomatosis that kills rabbits.



▲ **FIGURE 13.10.1** Rabbits reached plague numbers before the introduction of biological control.

John Carmemolla/Corbis Documentary/Getty Images

Another example is the prickly pear, which was brought to Australia on the First Fleet. It infested 25 million hectares of land in New South Wales and Queensland. This was eventually controlled by releasing a caterpillar that ate only prickly pear.

The caterpillar that ate the prickly pear and the myxoma virus that killed rabbits are two examples of a **biological control**.

In north Queensland, the native cane beetle was destroying sugar cane crops. In 1935, the cane toad was deliberately introduced from South America as a method of biological control. However, the cane toad did not reduce the population of cane beetles. Instead, it adjusted quickly to the tropical environment, eating almost anything it could swallow and spreading disease. Birds and animals that tried to eat the cane toad were poisoned. The rapid increase in cane toad numbers led to the decline of native frogs and reptiles in Queensland. Since then, cane toads have spread through Queensland and into New South Wales. They reached the Northern Territory in 1974 and Western Australia in 2009.



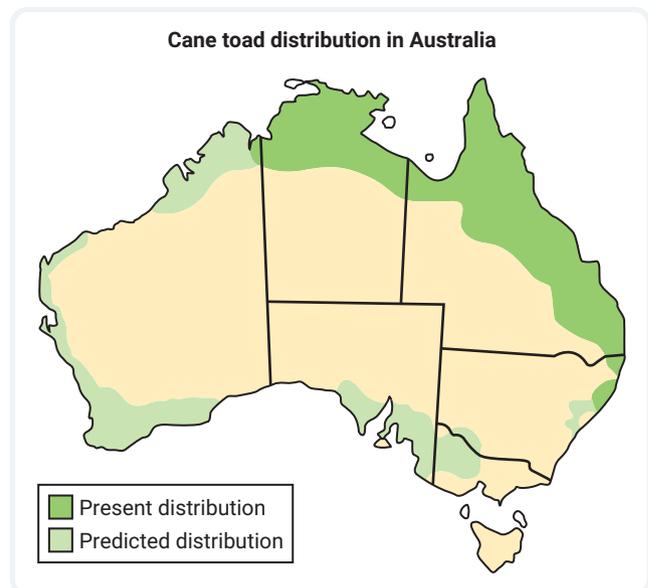
istock.com/vdovnyk

▲ **FIGURE 13.10.2** Prickly pear is an introduced species in Australia.

biological control
the reduction of a pest species by using natural enemies



Peter Yeeles/Shutterstock.com



▲ **FIGURE 13.10.3** The cane toad is an introduced species that has spread from New South Wales across to Western Australia as a result of a lack of natural predators.

▼ **TABLE 13.10.1** Species intentionally introduced to Australia

Species	Year of introduction	Reason for introduction
Foxes	1855	Fur trade, sport
European carp	1859	Food source, sport
Rabbits	1859	Sport
Cane toad	1935	Biological control of the cane beetle

▼ TABLE 13.10.2 Species accidentally introduced to Australia

Species	Location	How it happened
House mouse	Across Australia	Arrived on boats from England to Australia
Red-eared slider tortoise	New South Wales	Escaped from household pet aquariums
Pacific starfish	Victoria	Dumped with ballast water from international ships

13.10 LEARNING CHECK

- List** three species that have been introduced to Australia.
- Explain** why a lack of natural predators leads to an introduced species disrupting the ecosystem.
- Compare** invasive species and introduced species.
- In 2019, the Australian Government provided \$12 million towards controlling cane toads. **Explain** why cane toads pose a threat large enough to justify this spending.
- The rabbit-proof fence is an initiative that the Western Australian Government implemented in 1907 to protect the state. **Discuss** the use of the fence to keep rabbits out of Western Australia. **Consider** why it was thought to be necessary, the advantages of this strategy over other methods, and reasons that the fence may not succeed.



- Find out what species have been introduced to the area where you live. What impact have they had on the environment?



Weblink
Rabbit-proof fence

Video activity
Cane toads

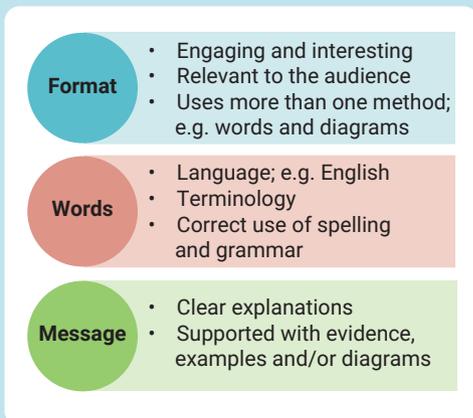


SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ investigating a local, national or global environmental issue
- ▶ communicating scientific information clearly and accurately via a format that is appropriate to the audience.

Communicating means to share information. To communicate effectively, it is important to consider how we are sharing the information so that the message is received. Figure 13.11.1 summarises key factors for communicating effectively.



▲ **FIGURE 13.11.1** Factors to consider for effective communication



Video
Science skills
in a minute:
Science
communication

**Science skills
resource**
Science skills
in practice:
Science
communication

UNDERSTANDING AN ENVIRONMENTAL ISSUE

AIM

To investigate an environmental issue to share an understanding about:

- what the problem is
- what caused the problem
- what is being, or has been done, to control the problem

MATERIALS AND EQUIPMENT

- access to the internet

PROCEDURE

- 1 Find out what environmental issues affect your area or state, the country or the world. Use a variety of sources such as your parents, teachers, library and the internet.
- 2 Choose one issue that you are interested in.
- 3 Write five questions to direct your research. These questions should address the information that you need to find to understand your chosen environmental issue; for example, 'Where does the issue occur?' or 'How does the issue affect the food web?'
- 4 Conduct research to answer your questions. Summarise the information, in your own words, noting its source, in a table like the one shown in the Results section.
- 5 Reflect on your information. If you have not developed a thorough understanding of the issue, write new questions to address what you still need to learn and then find the answers to these questions.

RESULTS

Use a table like the one below to summarise your information for your first question. Create a new table for each research question.

Question 1	
Summary of information	Source of information

COMMUNICATION

- Choose how you would like to use the information about the environmental issue. For example, you may educate others about the issue, inspire others to make individual changes, fundraise to put solutions into action, or advocate for changes to laws and standards.
- Choose an audience with whom to share what you have learned. This may be:
 - other students
 - young children
 - local, state or federal government representatives
 - your school
 - the broader community.
- Choose a mode of communication that will allow you to engage with your audience to achieve your goal. For example, a children's book would be suitable for young children, a letter to your local politician would address the government, or a newspaper article would reach the broader community. Other ideas are a website, an infographic, a poster, a fundraising event, a video, a podcast or a short story.
- Use your notes to explain your chosen environmental issue to your chosen audience.
- Collate the information about your sources in a bibliography. Your teacher will tell you what format to use; however, remember to include all relevant information such as the author, title, website name, URL and access date, and to list your sources in alphabetical order based on the author's surname.

13 REVIEW

REMEMBERING

- 1 Name** five biotic and five abiotic factors in a marine ecosystem.
- 2 Describe** the process of photosynthesis, including the substances that are used and produced.
- 3 Write** the word equation for cellular respiration.
- 4 Describe** the difference between an endangered species and an extinct species.
- 5 Define:**
 - a** producer.
 - b** consumer.
 - c** apex predator.
 - d** decomposer.
- 6 Describe** the flow of energy through an ecosystem.

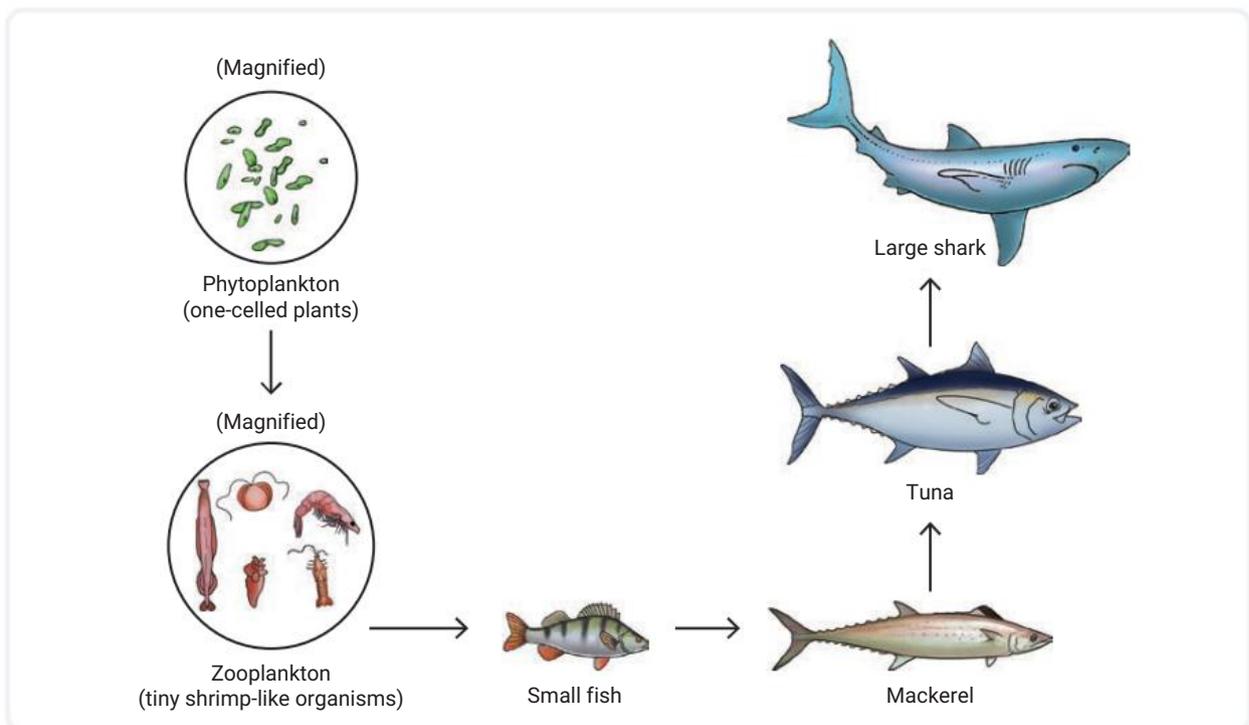
UNDERSTANDING

- 7 Explain** the difference between an environment and an ecosystem.
- 8 Explain** why producers are always at the bottom of a food chain or web.

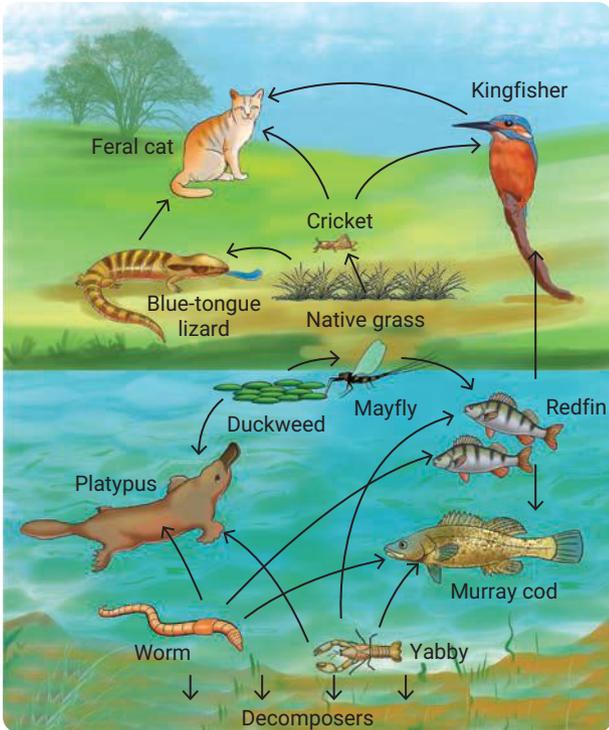
- 9** Why do organisms need cellular respiration?
- 10 Explain** the difference between a food chain and a food web.
- 11** Why is photosynthesis such an important process? **Explain** your answer in terms of energy.

APPLYING

- 12 Describe** how you can use quadrats and transects to study your local environment.
- 13 Draw** a food chain that includes:
 - a** cow, grass, human.
 - b** small bird, pollen, spider, bee.
 - c** fox, eucalyptus tree, koala, eagle.
- 14** The following diagram shows a food chain for a marine environment.
 - a Identify** the producer and the primary, secondary and tertiary consumers.
 - b Draw:**
 - i** an energy pyramid for the food chain.
 - ii** a biomass pyramid for the food chain.



15 Use the following diagram of a typical Australian food web to answer the questions.



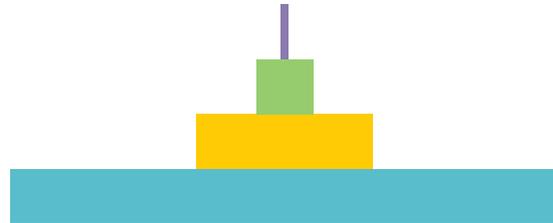
- State which organisms are producers and which are consumers.
- Give an example of a herbivore, an omnivore and a carnivore.
- Explain the difference between an autotroph and a heterotroph, and give an example of each from the food web.
- Write three food chains that are found in this food web.
- Explain the effect the feral cat has on the food web.
- Explain what might happen if the European rabbit was introduced into this community.

16 Aboriginal and Torres Strait Islander Peoples' seasonal calendars use a range of seasonal indicators. Describe what indicators in your local environment could be used to develop your own seasonal calendar.

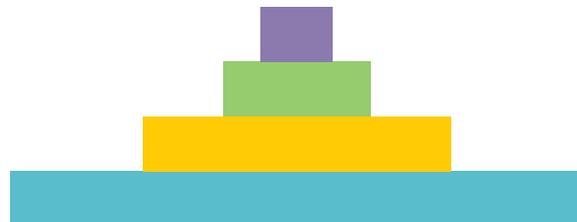
EVALUATING

- Variegated plants are plants with green and white stripes on their leaves. Would you expect these plants to grow as fast as non-variegated plants? Give reasons for your answer.
- Discuss the advantages and disadvantages of intentionally releasing introduced species into Australia.
- Extension: Construct a food chain that could be represented in each of the following pyramids.

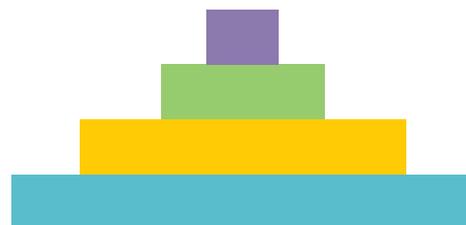
a Energy



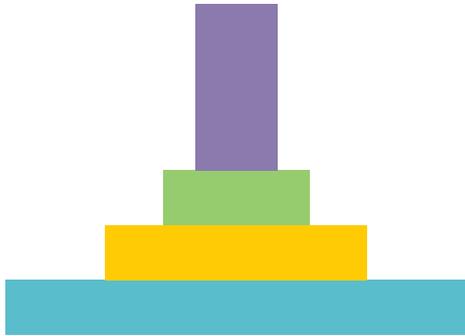
b Biomass



c Numbers



- 20 Extension: Is the following energy pyramid drawn to scale? **Explain** your answer.



- 21 With the introduction of the European rabbit and fox into Australia, the population of native bilbies declined dramatically. What conservation technique do you think would help increase the numbers of the bilbies? **Justify** your answer.
- 22 Feral cats have become one of the greatest threats to the survival of many native species.
- a **Explain** how a feral cat could affect an ecosystem.
 - b **Suggest** a method of solving this problem and **explain** why it would work.

CREATING

- 23 **Write** a sentence that uses each of the following groups of words.
- a Producer, consumer, apex predator
 - b Producer, herbivore
 - c Food chain, food web, ecosystem
 - d Autotroph, heterotroph, producer, consumer
 - e Decomposer, matter, cycle, producer
- 24 **Create** a flow chart to model how matter cycles through an ecosystem.
- 25 **Find** three species that have not been mentioned in this chapter, that have been introduced into Australia. How have these species affected the environment?
- 26 **Create** a food chain for the following information.
- One day, a bird saw a snake with a full belly, lazing in the late-afternoon sunshine. The bird thought, 'Mmm, I'm hungry.' It flew down and caught the snake for dinner. Earlier that day, the snake had been busy catching its own meal. Gliding by the pond, it had noticed a grasshopper nibbling on some grass. When a cheeky frog snapped up the grasshopper with its long, sticky tongue, the snake thought, 'Jackpot!' It slithered quickly to the edge of the pond and caught the frog as it was eating the grasshopper.

SCIENCE IN DEPTH STUDY

#13

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In summer, high temperatures, dry conditions and strong winds can lead to hundreds of fires burning across New South Wales. In the summer of 2019–20, many areas were devastated by large bushfires, including Bowning, Nowra, Tarcutta, Brogo, Carlaminda, Cooma, Monaro, Illawarra, Shoalhaven, Yarrabin and the Kybeyan Valley. The 2019–2020 fires burned around 5.5 million hectares of New South Wales bushland, which is approximately 7% of the state.

▲ The Blue Mountains

1 Connect what you've learned

At the start of this chapter, you summarised how you thought the plants and animals would have been affected during, immediately after, and one year after the fires. Add to your summary by including information about how each of the following would be affected at different times.

- Abiotic factors
- Biotic factors
- Food chains

2 Check your thinking

Choose one plant or animal species that is native to your local area. Brainstorm information about the ecosystem that it lives in, including the abiotic factors and biotic factors that it needs to survive.

Imagine that a fire destroyed the area. What would your organism need to survive in the environment again? How could these needs be met? How could the risk of a fire in the future be reduced?

3 Get into action

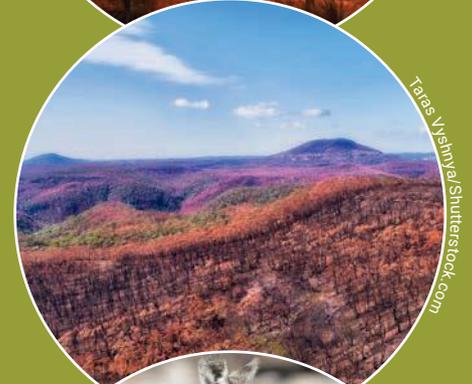
Use your answers from step 2 to develop a plan to protect the native species that you chose. In your plan, consider what needs to be done, who will do it, what resources you will need and how much it will cost.

4 Communicate

Create a radio, television or online advertisement to gain support for your action plan.



AAP Images/Supplied by DfES, Evan Collis



Taras Vyshnyak/Shutterstock.com



Lea Scaddan/Getty Images

▲ Bushfires have a major impact on bushland, and kill or injure many animals.

PERIODIC TABLE AND ATOMIC STRUCTURE

SYLLABUS OUTCOMES

A STUDENT:

- ▶ explains how uses of elements and compounds are influenced by scientific understanding and discoveries relating to their properties SC4-PRT-01
- ▶ uses a variety of ways to process and represent data SC4-WS-05
- ▶ uses data to identify trends, patterns and relationships, and draw conclusions SC4-WS-06

THE CHAPTER RELATED TO THIS FOCUS AREA IS:

- ▶ **CHAPTER 14** – THE PERIODIC TABLE AND ATOMIC STRUCTURE

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14

The periodic table and atomic structure

14.1 Atoms and elements (p. 482)

Atoms are the building blocks of all matter.

14.2 Atomic structure (p. 486)

Atoms contain subatomic particles. The number and arrangement of these particles determines the element.

14.3 The periodic table (p. 488)

The periodic table is an important and relevant tool in chemistry.

14.4 Extension: Electron arrangement (p. 492)

The arrangement of electrons around the nucleus of an atom follows a pattern that allows the arrangement to be predicted.

14.5 Atomic theory (p. 496)

The model of the atom has been developed over time by many scientists experimenting and proposing hypotheses.

14.6 WORKING SCIENTIFICALLY: Analysing data to identify trends (p. 500)

Modelling atomic structure

14.7 Properties of elements (p. 502)

The properties of elements can generally be predicted by their position on the periodic table.

14.8 WORKING SCIENTIFICALLY: Presenting data in tables (p. 506)

- 1 Identifying metal and non-metal elements
- 2 Investigating the properties of elements

14.9 Molecules and compounds (p. 510)

At the atomic level, substances can be classified as elements, compounds or molecules.

14.10 Models and chemical formulas (p. 514)

Elements and compounds can be represented in a variety of ways.

14.11 SCIENCE IN CONTEXT: Periodic table development (p. 516)

The periodic table has developed over time as more elements were discovered.



▲ FIGURE 14.0.1 Elements are widely used in a variety of products, including aluminium cans, copper wiring, and helium balloons.

Elements are substances that contain only one type of atom. Elements you might know of include hydrogen, helium, magnesium, aluminium and oxygen. They can be solids, liquids or gases. Many elements combine with other elements to make compounds and mixtures. However, there are also many elements that exist on their own, and are useful to us in our everyday lives.

Elements have a range of properties, including density, hardness, electrical conductivity, strength and the ability to conduct heat. These are all important properties that make them useful to us.

- ▶ Looking at Figure 14.0.1, what properties do you think the elements in these products have that make them useful?
- ▶ Are there any other elements you know about that we use? What properties do they have that make them useful?

#14 DIVE INTO SCIENCE!

At the end of this chapter, you can complete Science in Depth Study #14. You can use the information you learn in this chapter to complete the project.

Assessments

- Prior knowledge quiz
- Chapter review questions
- End-of-chapter test
- Depth study: Science investigation

Videos

- Science skills in a minute: Representing data (14.6); Presenting data in tables (14.8)
- Video activities: What is an atom? (14.1); The discovery of the atom (14.1); Atomic structure (14.2); Introduction to the periodic table (14.3); Electron shells (14.4); Noble gases (14.7)

Science skills resources

- Science skills in practice: Data tables (14.8)
- Extra science investigations: Observing different elements (14.1); Comparing properties (14.7); Modelling elements and compounds (14.10)

Interactive resources

- Simulations: Build an atom (14.4); Rutherford scattering (14.5); Build a molecule (14.10)
- Label: Parts of an atom (14.2); Molecule or compound? (14.9)
- Drag and drop: Properties of elements (14.7)

14.1 Atoms and elements

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ explain how atoms are the building blocks of all matter
- ✓ distinguish between an atom and an element
- ✓ recognise that atoms and elements can be represented by names, symbols and diagrams
- ✓ recall the three categories used to classify all elements.



Video activities
What is an atom?
The discovery of the atom

Quiz
Elements

Extra science investigation
Observing different elements

GET THINKING

In this module, you will learn that the building blocks of all matter are tiny particles called atoms. What do you think makes atoms different from each other?

Atoms: the building blocks of all matter

Imagine a majestic snow-capped mountain. From a distance the snow looks like it is one big piece, but up close we know it is made up of many trillions of snowflakes. Likewise, we know a sandy beach is made up of billions and billions of grains of sand. Whether we refer to individual snowflakes or sand grains, they are both the building blocks of something bigger.

Similarly, our lives contain a wide variety of objects, built from smaller things, made from many different materials, but they all have one thing in common. If you were able to cut any object in half, halving it in size, over and over, millions of times, you would eventually get the basic unit of matter that can no longer be divided – but still has the same properties as the original substance. This smallest unit is called an **atom**.

Atoms are much too small to see with the human eye. One single grain of sand is actually a large collection of atoms – billions of billions of them!

atom

the smallest part of an element that gives the element its chemical properties



▲ **FIGURE 14.1.1** The metal copper is a shiny orange-brown solid made up of copper atoms.

Why are we all different?

If everything in the universe is made of the same thing – atoms – then why doesn't everything look the same? The answer is that there are 92 naturally-occurring different types of atoms that make up everything you've ever seen. The properties of any object depend on their atoms and how they are connected.

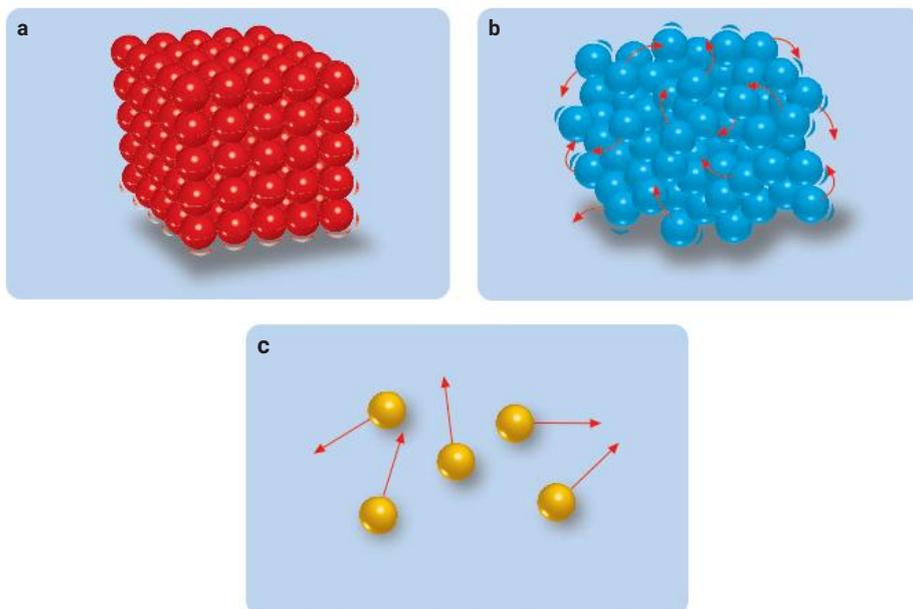
For example, the metals copper and zinc are quite different. Copper (Figure 14.1.1) is a shiny orange-brown solid at room temperature. Zinc (Figure 14.1.2) is a shiny grey solid at room temperature. These two metals look different because copper is made up of copper atoms and zinc is made up of zinc atoms.



▲ **FIGURE 14.1.2** The metal zinc is a shiny grey solid made up of zinc atoms.

What do atoms look like?

It is hard to imagine what atoms look like because they are so small. The diagrams in Figure 14.1.3 represent what three different pure substances would look like if we could magnify them enough to see how the atoms would look and how they were arranged. The individual atoms are represented by the small, coloured spheres. Each pure substance shown has different coloured spheres (atoms aren't individually coloured, but scientists represent them this way to tell them apart). This shows that the atoms of each pure substance are different from each other and so the substances themselves must also be different. Diagrams such as these are one way to visualise the type and arrangement of atoms in different substances.



▲ **FIGURE 14.1.3** (a) A solid pure substance made up of one type of atom; (b) a liquid pure substance made up of one type of atom; (c) a gaseous pure substance made up of one type of atom

An element contains identical atoms

The atoms represented as red in Figure 14.1.3a are all the same colour and size. This is also true for the blue and yellow atoms. This means all three substances are pure; each of them is made up of only one type of atom.

element

a pure substance made up of only one type of atom; cannot be broken down into a simpler substance

transuranic

an element that comes after uranium in the periodic table

property

a characteristic or feature of a substance

metal

a chemical element that has certain properties, such as conducting heat and electricity, being malleable and being ductile

non-metal

a chemical element that has certain properties, such as being brittle, having a non-shiny appearance and low melting point

metalloid

a chemical element that has properties in between those of a metal and a non-metal

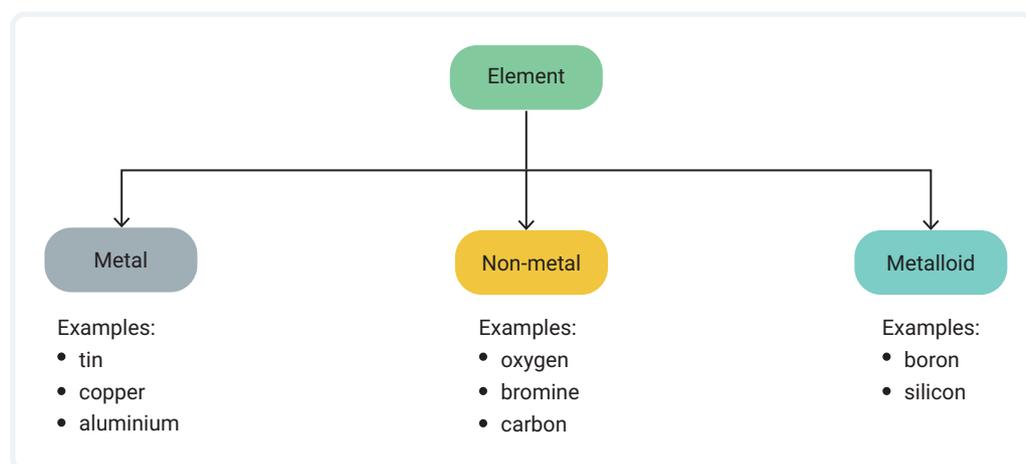
The illustrations represent a type of pure substance known as an **element**. An element is a pure substance that is made up of only one type of atom. Elements cannot be broken down into other simpler substances because they already exist in their most basic form. Each element has a name and is represented by a chemical symbol. The symbol for each element often comes from the element's name. For example, the element chlorine is represented by the symbol Cl.

The metal copper, represented by the symbol Cu, is an element because it is made up only of copper atoms. If it were possible to cut a piece of copper in half, halving the size, over and over again until it was down to the individual atoms, they would still be copper atoms and therefore it would still be copper. The metal zinc is represented by the symbol Zn.

Today, scientists recognise 118 different elements. The first 92 elements occur naturally on Earth, while the last 26 were created by scientists, and many only existed in the laboratory for fractions of a second. These human-made or synthesised elements are called **transuranic**.

Elements, much like the atoms they are made of, have their own set of characteristics, which scientists call **properties**. Examples of properties are colour, melting point and density. It is these properties that allow elements to be classified, or grouped, into three categories: **metals**, **non-metals** and **metalloids**. This is shown in Figure 14.1.4.

Approximately 80 per cent of the known elements are metals, and they all have similar properties. We will learn more about these metallic properties in Module 14.7.

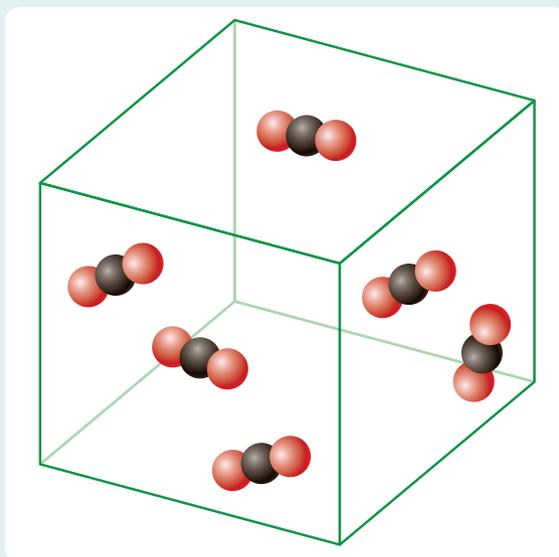


▲ FIGURE 14.1.4 The classification of elements as metal, non-metal or metalloid

14.1 LEARNING CHECK

14.1

- 1 **Recall** what all matter is made up of.
- 2 **Identify** the names of the elements represented by the following symbols.
 - a Cl
 - b Cu
 - c Zn
- 3 All elements are classified into three categories. **List** them.
- 4 **Create** a question and answer for each of the words below. Make sure the word is included in both the question and the answer.
 - a Property
 - b Element
 - c Metalloid
- 5 **Explain** what is meant by the phrase 'atoms are the building blocks of all matter'.
- 6 Refer to the figure below to answer the following questions.



- a **Determine** the total number of atoms represented here.
 - b **Explain** what the different colours represent.
- 7 **Analyse** Figure 14.1.4 to give other examples of metals, non-metals and metalloids.
 - 8 **Compare** an atom and an element, discussing their similarities and differences.

14.2 Atomic structure

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe the properties of particles that make up atoms
- ✓ create a model to show the structure of an atom
- ✓ compare the composition and structure of atoms of different elements.



Video activity
Atomic structure

Interactive resource
Label: Parts of an atom

subatomic particle

a particle inside an atom, such as a proton, a neutron or an electron

proton

a positively charged particle in the nucleus of an atom

neutron

a particle in the nucleus of an atom that does not have an electrical charge

electron

a negatively charged particle that moves in space around the nucleus of an atom

nucleus

the dense centre of an atom; positively charged

shell (electron shell)

an energy level around the nucleus of an atom containing electrons of the same energy

planetary atomic model

a model of the atom showing electrons orbiting the nucleus

GET THINKING

How are atoms and elements linked? What is it about an atom that makes it oxygen, carbon or hydrogen? As you complete this module, think about ways to represent the composition of the atom in written form.

Particles in the atom

All atoms have a common structure and most contain the same three subatomic particles – protons, neutrons and electrons. Collectively, these are called **subatomic particles** and, when arranged in a specific way, they make up all atoms.

Protons are positively charged particles. **Neutrons** are neutral particles (have zero charge) and are about the same mass as a proton. **Electrons** are negatively charged particles and are about 2000 times smaller than a proton or a neutron. Table 14.2.1 describes the subatomic particles in an atom.

TABLE 14.2.1 Subatomic particles in an atom

Subatomic particle	Symbol	Location in the atom	Charge	Relative mass (atomic mass unit – amu)
Proton	p	Nucleus	+1	1
Neutron	n	Nucleus	0	1
Electron	e	In shells around the nucleus	-1	$\frac{1}{1840}$

Structure of the atom

All atoms have a **nucleus** that includes at least one proton, and all atoms have at least one electron in a **shell** (an energy level) around the nucleus. The simplest element, hydrogen, has one proton in the nucleus and one electron in a shell. The simplest form of hydrogen does not have any neutrons in the nucleus.

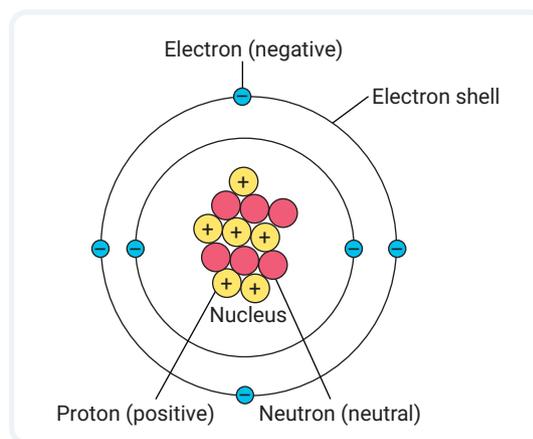
All other elements have protons and neutrons in the nucleus and electrons around the nucleus. For example, an atom of carbon has six protons and six neutrons in the nucleus and six electrons around the nucleus in shells (Figure 14.2.1).

Atoms are electrically neutral. In all atoms, the number of positive protons is equal to the number of negative electrons. This is why an atom has no overall charge.

We represent atoms using a **planetary atomic model** (Figure 14.2.1). You will learn more about atomic models later in this chapter.

How are atoms of elements different?

Atoms of the same element always have the same number of protons. It is the number of protons in the nucleus that defines the element. For example, all hydrogen atoms have one proton in their nucleus, all carbon atoms have six protons, and all uranium atoms have 92 protons.



▲ FIGURE 14.2.1 A planetary atomic model of carbon, showing the arrangement of subatomic particles

The relative sizes of particles in the atom

☆ ACTIVITY

Materials and equipment

- tape measure that will measure at least 2 m
- piece of chalk or a marker
- butcher's paper

Procedure

- 1 Draw a line that is 1 mm long. This will represent an electron.
- 2 A proton or a neutron is approximately 2000 times larger than an electron. Calculate the length of the line you would need to draw that is 2000 times larger than the 1 mm line you just drew. Check your answer with other groups or your teacher to see if you are correct.
- 3 Draw your new line. This represents the size of a proton.

Analysis

- 1 Did the size difference surprise you? In what way?
- 2 Is it easier to 'see' the difference by looking at numbers or with an activity like this? Why do you think this is?

14.2 LEARNING CHECK

- 1 **Identify** the one element that does not have neutrons.
- 2 **Describe** the mass, charge and location in the atom of protons, neutrons and electrons.
- 3 **Explain** what makes an atom of one element different from an atom of another element.

14.3 The periodic table

BY THE END OF THIS MODULE YOU WILL BE ABLE TO:

- ✓ compare Mendeleev's periodic table with the current version of the periodic table
- ✓ identify groups, periods, metals, non-metals and metalloids on the periodic table
- ✓ explain the importance of unique chemical symbols
- ✓ explain the link between electron configuration and the position of atoms on the periodic table.



Video activity
Introduction to the periodic table

GET THINKING

The periodic table, first developed in 1869, combines much of scientists' knowledge about chemistry into a single page. Do you think the periodic table remains an important and relevant tool in chemistry today?

The original periodic table

periodic table

a method of arranging elements by increasing atomic number

The **periodic table** of elements was originally developed by Russian chemist Dmitri Mendeleev (1834–1907). It catalogues all the known elements in the universe. The arrangement of elements in the periodic table also provides patterns and clues about their properties.

In 1869, Mendeleev discovered that by grouping the 63 known elements into columns by their properties and into rows by their mass (generally from lightest to heaviest), there were patterns within the rows and columns of the table that was produced (Figure 14.3.1). He also proposed the densities and weights, known as **atomic weights**, of many of the known elements. The history of the development of the periodic table will be further examined in Module 14.11.

atomic weight

the mass of one atom of an element, measured in atomic mass units

Tabelle II.

Reihen	Gruppe I. — R ⁰	Gruppe II. — R ⁰	Gruppe III. — R ⁰ ³	Gruppe IV. RH ⁴ R ⁰ ²	Gruppe V. RH ⁵ R ⁰ ⁵	Gruppe VI. RH ⁶ R ⁰ ³	Gruppe VII. RH R ⁰ ⁷	Gruppe VIII. — R ⁰ ⁴
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	—
9	(—)	—	—	—	—	—	—	—
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	—
12	—	—	—	Th=231	—	U=240	—	—

der chemischen Elemente.

▲ FIGURE 14.3.1 Dmitri Mendeleev's periodic table

Science & Society Picture Library/Getty Images

The modern periodic table

While Mendeleev organised his periodic table by increasing weight of elements, the modern periodic table (Figure 14.3.2) organises elements by increasing **atomic number**. The atomic number of an element is the number of protons found in the nucleus. For example, carbon has six protons, so it has an atomic number of 6.

atomic number
the number of protons found in the nucleus of an atom

Group 1																		18	
1	1																	2	
	H																	He	
	hydrogen																	helium	
	3	4											5	6	7	8	9	10	
2	Li	Be											B	C	N	O	F	Ne	
	lithium	beryllium											boron	carbon	nitrogen	oxygen	fluorine	neon	
	11	12											13	14	15	16	17	18	
3	Na	Mg											Al	Si	P	S	Cl	Ar	
	sodium	magnesium											aluminium	silicon	phosphorus	sulfur	chlorine	argon	
	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	
	potassium	calcium	scandium	titanium	vanadium	chromium	manganese	iron	cobalt	nickel	copper	zinc	gallium	germanium	arsenic	selenium	bromine	krypton	
	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	
	rubidium	strontium	yttrium	zirconium	niobium	molybdenum	technetium	ruthenium	rhodium	palladium	silver	cadmium	indium	tin	antimony	tellurium	iodine	xenon	
	55	56		72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	
6	Cs	Ba		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	
	caesium	barium		hafnium	tantalum	tungsten	rhenium	osmium	iridium	platinum	gold	mercury	thallium	lead	bismuth	polonium	astatine	radon	
	87	88		104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	
7	Fr	Ra		Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og	
	francium	radium		rutherfordium	dubnium	seaborgium	bohrium	hassium	meitnerium	darmsstadtium	roentgenium	copernicium	nihonium	flerovium	moscovium	livermorium	tennessine	oganesson	
	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71				
	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu				
	lanthanum	cerium	praseodymium	neodymium	promethium	samarium	europium	gadolinium	terbium	dysprosium	holmium	erbium	thulium	ytterbium	lutetium				
	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103				
	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr				
	actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendelevium	nobelium	lawrencium				

▲ FIGURE 14.3.2 The modern periodic table (as of June 2024)

Every square in the table contains an element symbol (e.g. H), the element name (e.g. hydrogen) and the atomic number (e.g. 1). If you look along each row and read it like lines of text in a book, then you will see the elements are arranged in order of increasing atomic number.

Names and chemical symbols

chemical symbol

a letter or letters of the Latin alphabet used to represent an atom of a specific element

The periodic table provides the name and **chemical symbol** of every known element. We use symbols as abbreviations for elements, because it is quicker and easier than writing the full word. The use of chemical symbols is a type of internationally recognised 'shorthand' that has no language barrier – the chemical symbol for each element is the same worldwide.

The first letter of the chemical symbol is always a capital. If there is a second letter, it is always lower case. Many of the symbols are the first letter of the name of the element, such as H for hydrogen and C for carbon. Other elements have two letters in their symbols, such as Ca for calcium and Co for cobalt. This is so the elements carbon, calcium and cobalt are not confused (Figure 14.3.3). The chemical symbols of some other elements seem to have no relationship to their names, such as Fe for iron and Sn for tin. This is because the names of these elements come from another language. The Latin word for iron is *ferrum* and for tin it is *stannum*.



▲ FIGURE 14.3.3 The metals carbon, calcium and cobalt all start with the letter C. They are given different chemical symbols to tell them apart: carbon is C, calcium is Ca and cobalt is Co.

Features of the periodic table

group

a vertical column on the periodic table

period

a horizontal row on the periodic table

The periodic table gives a range of information about the elements. The vertical columns are called **groups**. There are 18 groups in total, and the group numbers are on the top of each column. The horizontal rows are called **periods**. There are seven periods, and the period numbers are next to each row on the left. These periods correspond to the electron shells. You will learn about this in Module 14.4.

What are those extra rows?

There are two extra rows of elements at the base of the table. These are not extra periods. They fit into the periodic table in periods 6 and 7. Period 6 has a gap between Ba (56) and Hf (72). The missing elements are in the first of the rows at the base of the table, from La (57) to Lu (71). The elements in this row are called the lanthanoids. The second row at the base of the table fits into period 7, in the same way. The elements in this row are called the actinoids.

Metals, non-metals and metalloids

The periodic table contains many patterns. One simple pattern shown in Figure 14.3.2 is the elements that are metals, non-metals and metalloids. The elements shaded yellow are metals. Most elements are metals. The light blue elements on the right of the table are the non-metals. The purple strip between them is the metalloids – elements with properties of both metals and non-metals (Figure 14.3.4). We will look at the properties of elements in more detail in Module 14.7.



▲ FIGURE 14.3.4 Metals, such as magnesium, are on the left side of the periodic table; non-metals, such as chlorine, are on the right; and metalloids, such as silicon, are between the metals and non-metals.

14.3 LEARNING CHECK

- 1 **Recall** what a period and a group are on the periodic table.
- 2 **Identify** the period number of the following elements.
 - a Boron
 - b Helium
 - c Potassium
- 3 **Identify** the group number of the following elements.
 - a Strontium
 - b Phosphorus
 - c Tin
- 4 Each element on the periodic table has a unique chemical symbol. **Explain** why this is important.
- 5 **Compare** the organisation of Mendeleev's original periodic table to the current organisation of the periodic table.

14.4 Extension: Electron arrangement

BY THE END OF THIS MODULE YOU WILL BE ABLE TO:

- ✓ describe how electrons are arranged in an atom
- ✓ predict the arrangement of electrons in atoms
- ✓ explain how the periodic table gives information on electron arrangement.



Interactive resource
Simulation:
Build an atom

Video activity
Electron
shells

electron configuration
the arrangement of
electrons in electron
shells in an atom

GET THINKING

How would you find out the number of electrons in an element using the periodic table? What piece of information can you use? Explain why this information can help you determine the number of electrons.

Electron configuration

The arrangement of electrons in energy shells is called the **electron configuration**. The electron configuration of any atom can be determined by knowing this set of rules.

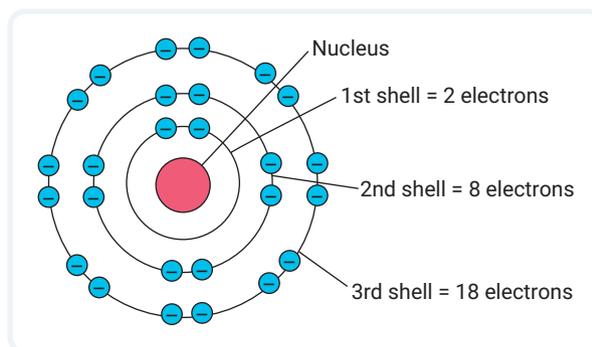
- Rule 1 – Each shell has a maximum number of electrons given by the formula $2n^2$.
- Rule 2 – Electrons fill the lower shells first.
- Rule 3 – Electrons fill each shell to a certain number, then move on to the next shell.

Using the formula $2n^2$

The first thing to know is how many electrons can fit into each shell. You can find the maximum number of electrons that can fit into a shell by applying the formula $2n^2$, where n represents the number of the electron shell (Table 14.4.1 and Figure 14.4.1).

▼ TABLE 14.4.1 The maximum number of electrons in each electron shell

Shell number (n)	Maximum number of electrons
1	$2 \times 1^2 = 2$
2	$2 \times 2^2 = 8$
3	$2 \times 3^2 = 18$
4	$2 \times 4^2 = 32$
5	$2 \times 5^2 = 50$



▲ FIGURE 14.4.1 The maximum number of electrons in each shell is determined by the $2n^2$ rule.

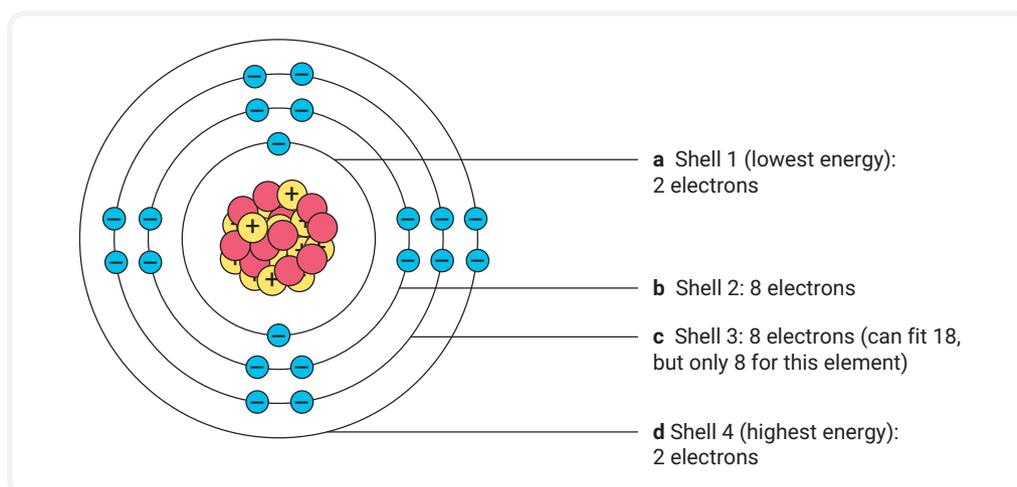
Now you know the maximum number of electrons that can fit in any shell, you can move onto using rules 2 and 3 to predict the electron configuration for the first 20 elements in the periodic table.

- Rule 2 – Electrons fill from the lowest shells first (the shells closest to the nucleus; these are the shells with the lowest energy).
- Rule 3 – Electrons fill the shells to a certain number, then move on to the next shell. They may not entirely fill the shell.

For the first 20 elements, they fill in a specific order shown by a–d in Figure 14.4.2:

- 1 First shell ($n = 1$) fills until it has two electrons in the shell.
- 2 Then the second shell ($n = 2$) fills until it has eight electrons in the shell.
- 3 Then the third shell ($n = 3$) fills until it has eight electrons (note that this shell can hold 18 but fills with only eight electrons at this stage).
- 4 Then the fourth shell ($n = 4$) fills until it has two electrons (this is the shell with the highest energy).

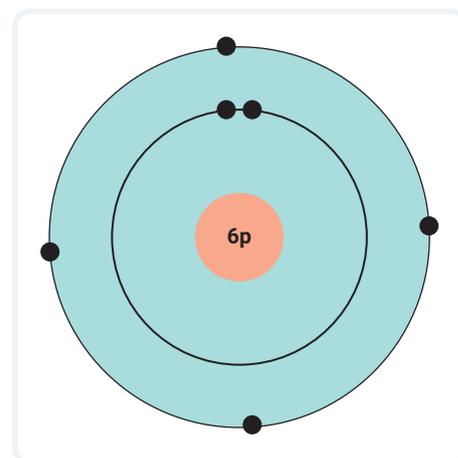
If you follow these rules, in order, you can predict the arrangement of electrons in any element up to calcium (atomic number 20).



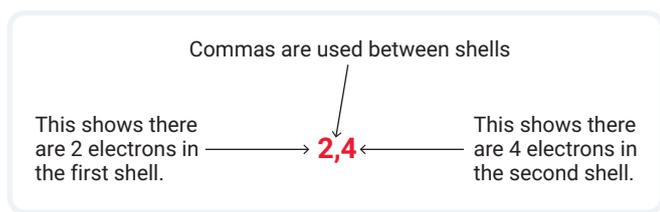
▲ FIGURE 14.4.2 The rules show that the atoms fill their electron shells in the order shown.

Let's look at the example of carbon with six electrons (Figure 14.4.3). Following the rules above:

- two electrons go into the first shell. It is now full and there are four electrons remaining
- four electrons go into the second shell. There are no electrons remaining.



▲ FIGURE 14.4.3 The planetary atomic model of the carbon atom



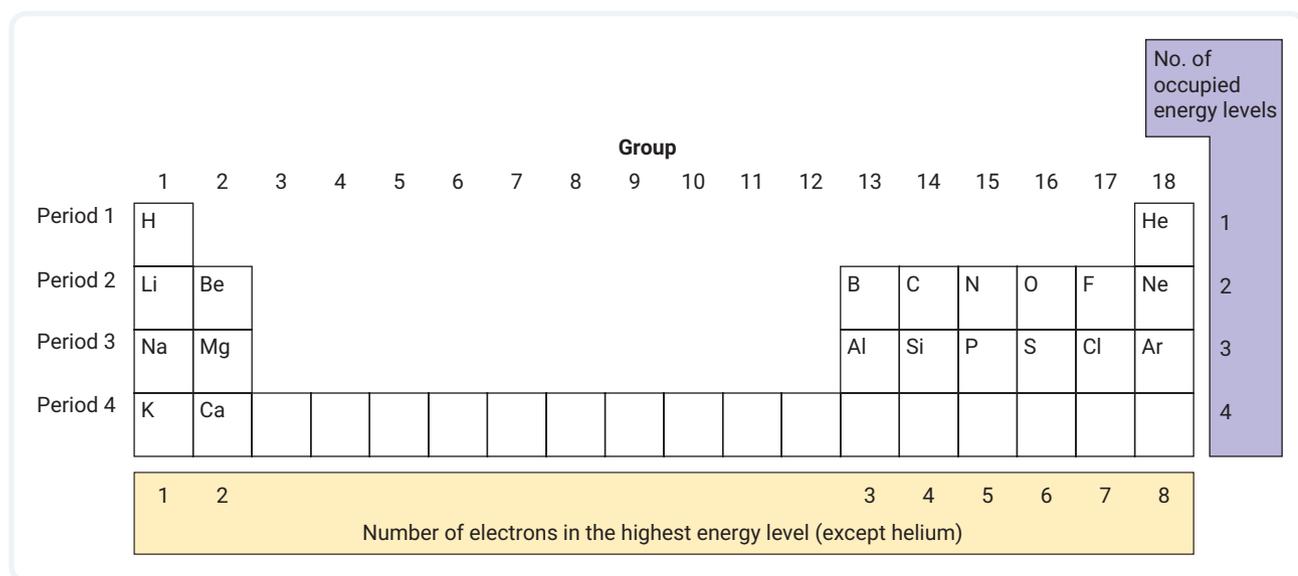
▲ FIGURE 14.4.4 The electron configuration of carbon

Representing electron configuration

The electron configuration of carbon is represented in Figure 14.4.4. Configurations written in this way have links to the position of the atom in the periodic table and provide more complex information about the way electrons are arranged in atoms.

Electron arrangement and the periodic table

The electron arrangement of an element is directly related to its position on the periodic table (Figure 14.4.5). The electron arrangement of an atom can tell you about how the atom will react with other atoms. (Reactions relate to the bonding between different atoms, which will be part of your Stage 5 studies.)



▲ FIGURE 14.4.5 A periodic table showing the number of electrons in the highest energy electron shell below each group

If we look at group 1, we see the following electron configurations:

- H = 1
- Li = 2,1
- Na = 2,8,1
- K = 2,8,8,1

All elements in group 1 have one electron in their highest energy shell.

You can repeat this process for elements in group 2: they all have two electrons in their highest energy shell. This pattern repeats across groups 1, 2 and 13–18. You can see the number of electrons in the highest shell listed below the periodic table in Figure 14.4.5.

The electrons in the highest energy shell are known as **valence electrons**.

valence electron

an electron in the highest energy shell of an atom

Elements that have the same number of valence electrons are in the same group on the periodic table and behave in similar ways in chemical reactions.

The electron configurations of the first 12 elements in the periodic table are shown in Table 14.4.2.

▼ TABLE 14.4.2 The electron configurations of the first 12 elements

Element	Number of electrons	Electron configuration
Hydrogen	1	1
Helium	2	2
Lithium	3	2,1
Beryllium	4	2,2
Boron	5	2,3
Carbon	6	2,4
Nitrogen	7	2,5
Oxygen	8	2,6
Fluorine	9	2,7
Neon	10	2,8
Sodium	11	2,8,1
Magnesium	12	2,8,2

14.4 LEARNING CHECK

- 1 What is the maximum number of electrons that can fit into the third shell?
- 2 **Write** the electron configuration of:
 - a fluorine (9 electrons).
 - b potassium (19 electrons).
- 3 What elements are represented by these electron configurations?
 - a 2,3
 - b 2,8
- 4 A student says that the electron configuration of an element is 4,2.
 - a **Explain** why this electron configuration cannot exist.
 - b **Write** the correct electron configuration of this element.
- 5 What information can you gain about an element's electron configuration by knowing what period it is in?

14.5 Atomic theory

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ state the atomic theory
- ✓ describe the contributions of scientists to our understanding of atomic structure
- ✓ demonstrate through a timeline of events that our understanding of atomic structure is an accumulation of the work of different scientists over time.



Interactive resource
Simulation: Rutherford scattering

GET THINKING

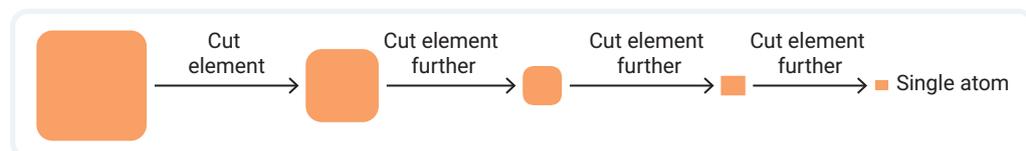
What is the one thing that all matter in the universe has in common? Everything is made of atoms! List three things you already know about atoms and elements.

What is atomic theory?

Our knowledge of atoms and elements has grown and evolved over time, with the discoveries and contributions of many scientists. It was only late in the 19th century that the first subatomic particles were discovered.

How do we know about atoms?

About 460 BCE (nearly 2500 years ago), the Greek philosopher Democritus was the first person to propose the concept of an atom. His theory suggested that if you kept cutting something into smaller pieces, you would eventually get a piece that could not be cut any smaller (Figure 14.5.1). The word 'atom' comes from the Greek word *atomos*, which means 'indivisible' (cannot be divided). Since then, many scientists have performed experiments that confirmed the existence of atoms. Scientists also discovered that within atoms are even smaller subatomic particles, and they worked out how the subatomic particles are arranged in an atom.



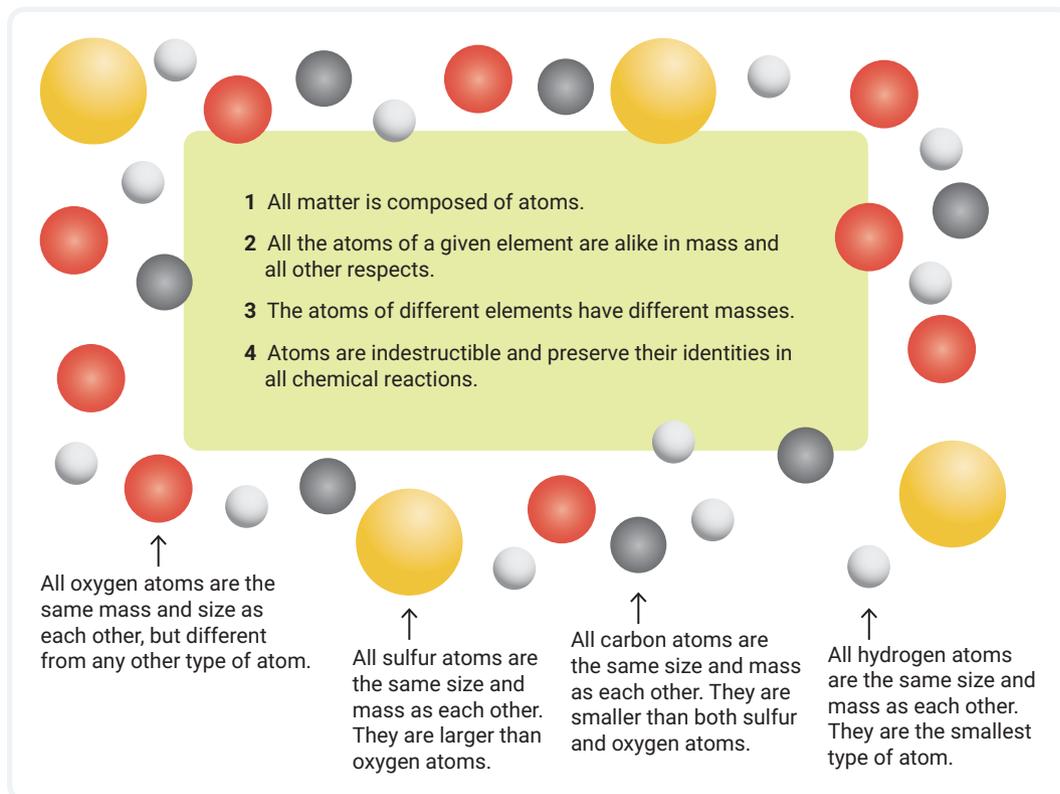
▲ FIGURE 14.5.1 If it was possible to cut an element into smaller and smaller pieces, you would eventually reach the smallest form of that element – the atom.

As scientific knowledge increased, scientists were able to perform experiments that confirmed or rejected theories about atoms. The problem with atoms is that, even with modern technology such as electron microscopes, we cannot see them to confirm their structure. Thus, all the descriptions we have of the atom are models.

Models are useful because they help us to visualise something too small to see. Models are not perfect and are improved over time as discoveries are made and new technology is invented. There have been many versions of the atomic model and it is still being developed.

Dalton's model of the atom

John Dalton (1766–1844) proposed the first modern model of the atom. He performed experiments and examined the results of other scientists' experiments. His conclusion was the same as that of Democritus. The results could only be explained if matter was made of small particles. He made several important conclusions about atoms and elements that are still accepted today (Figure 14.5.2).



▲ FIGURE 14.5.2 Dalton's conclusions about the atom

Thomson's plum pudding model

Since the 1850s, scientists have conducted experiments with **cathode ray** tubes.

- Cathode ray tubes pass an electric current through a piece of metal called a cathode.
- In the 1800s, scientists produced a glowing beam (Figure 14.5.3), but no-one knew what it was made from.
- When the metal cathode was changed to a different metal element, an identical glowing beam was produced.
- Scientists concluded that all metals (and all materials used) made exactly the same beam.
- This meant that something in atoms was producing the beam. But they did not know what it was!

cathode ray

a beam of electrons produced by a cathode ray tube

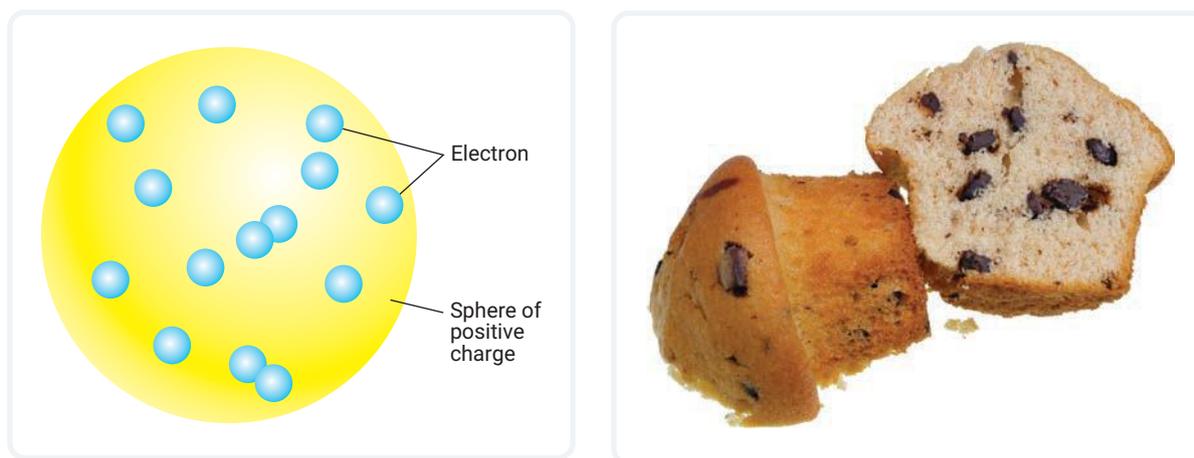


Charles D. Winters/Science Source/
Science Photo Library

▲ FIGURE 14.5.3 A cathode ray tube fires electrons that can be bent by electric and magnetic fields.

The British scientist J.J. Thomson (1856–1940) performed experiments in 1897 that showed the beam could be bent by an electric field. He concluded that the beam was made of tiny negatively charged particles. He knew they were negative because they were attracted to a positive charge inside the cathode ray tube. We now know these negative particles as electrons. Every material used in the cathode ray tube produced the same particles. Thus, Thomson concluded that the particles (electrons) were found in all types of atoms.

Thomson proposed a model of the atom that advanced the previous Dalton model. Atoms are usually electrically neutral, so the fact that they contained negative particles meant they also had to contain the same number of positive particles. Thomson proposed that the negatively charged electrons were contained inside a positively charged sphere – like fruit spread through a Christmas pudding or chocolate chips in a muffin. This is why Thomson’s model of the atom is often referred to as the ‘plum pudding model’ (Figure 14.5.4).



▲ FIGURE 14.5.4 Thomson’s plum pudding model. A muffin with chocolate chips is a good model for the plum pudding model. In this model, the muffin is the positive charge and the chocolate chips are the electrons.

Rutherford’s discoveries

New Zealand scientist Ernest Rutherford (1871–1937) further investigated the structure of the atom by testing Thomson’s model. Rutherford used very thin gold foil, just a few atoms thick, and fired **alpha particles** at the foil (Figure 14.5.5). An alpha particle is a helium nucleus, consisting of two protons and two neutrons, which gives it an overall positive charge. If the gold atom were like a plum pudding, then all the alpha particles should pass through the foil with minimal change of direction.

Rutherford was surprised to find that a small proportion of the alpha particles were deflected or bounced backwards. There was something in the gold atoms that blocked the path of the alpha particles. Rutherford suggested this was due to the atoms having a positive charge, concentrated in a structure he called the nucleus. This positive nucleus was repelling the positive alpha particles and changing their path. Therefore, he concluded that the plum pudding model was incorrect.

alpha particle

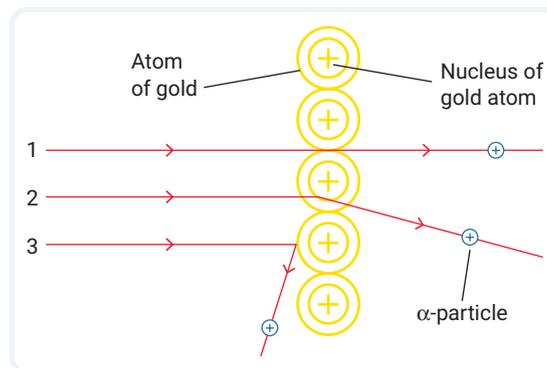
a helium nucleus (two protons and two neutrons) emitted when unstable larger nuclei decay

Rutherford proposed a new model of the atom. He proposed that atoms:

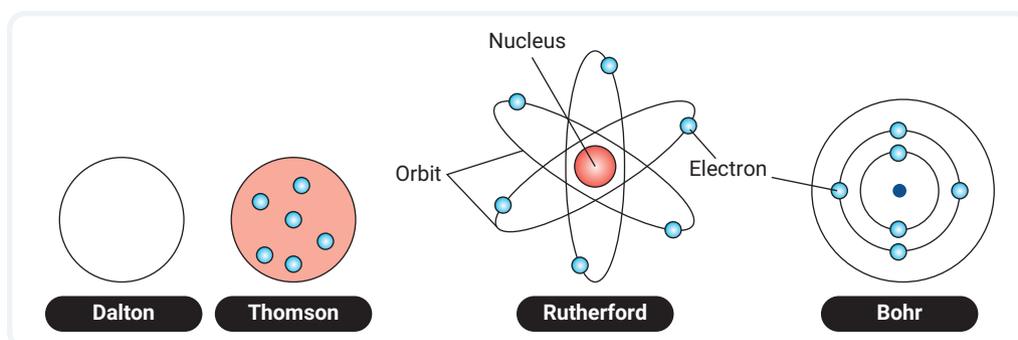
- were mostly empty space
- had positively charged protons in a nucleus in the centre
- had negatively charged electrons outside the nucleus.

Bohr's model

One of the problems with Rutherford's model was that he did not know how the electrons were arranged. He proposed they orbited like planets around the nucleus. Niels Bohr (1885–1962) proposed that electrons were arranged in shells, or energy levels, around the nucleus (Figure 14.5.6). His theory was that electrons in the same shell had the same energy. We refer to Bohr's model as the planetary atomic model.



▲ FIGURE 14.5.5 Rutherford's gold foil experiment



▲ FIGURE 14.5.6 The development of the model of the atom

Chadwick's discovery of the neutron

The model of the atom still had some problems that scientists couldn't explain, with the mass of the nucleus not matching the proposed particles and structure. The suggested arrangement of protons and electrons had a smaller mass than the actual mass measured. The atom was too heavy, indicating some other particles were present. James Chadwick proposed that the nucleus also contained electrically neutral particles. He conducted experiments to show that this particle was present in atoms. We know this particle as the neutron.

14.5 LEARNING CHECK

- 1 **State** three features of atoms as proposed by Dalton.
- 2 **Describe** the differences between Dalton's and Thomson's models of the atom.
- 3 **Describe** Rutherford's experiment and how it advanced the previous atomic model.
- 4 **Explain** one benefit and one limitation of atomic models.
- 5 **Create** a series of labelled diagrams to show how the atomic model has changed over time. Include the name of the scientist(s) and part(s) of the atom discovered.



Analysing data to identify trends

SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ creating models of the first 18 elements showing protons, neutrons and electrons
- ▶ analysing models to identify trends in data.

Scientists conduct investigations to analyse data and determine if trends are occurring. This has many uses as we can use trends to predict weather, or how a particular material might behave if it is used to build an object, or what chemical might form if we add substances together.

Data can include tables, graphs, models and images. All of these types of data can be analysed to look for patterns. For example, you might note that whenever you add two particular types of chemicals together you always get the same product. This lets you predict what might occur if you add other chemicals together.

Trends may be obvious, or sometimes harder to find. Things to look out for when analysing data for trends:

- results that repeat. If you get the same result in an experiment, this might suggest a trend
- results that increase (or decrease) in a constant way. If your results in an experiment are always doubling, then you might predict that this will continue if you were to test further.



Video
Science skills
in a minute:
Representing data

MODELLING ATOMIC STRUCTURE

AIM

To create models of the first 18 elements showing numbers of protons, neutrons and electrons

MATERIALS AND EQUIPMENT

You can do this activity by creating a picture, using plasticine, creating a digital image, or building a 3D model using polystyrene or other materials. Consult with your teacher to see what materials are available for you to use.

PROCEDURE

Use the information in Modules 14.2 and 14.4 to create models of the first 18 elements. Table 14.6.1 shows you the information you need to create these models accurately.

Before you start, ask yourself:

- Where in the atom are the protons and neutrons and electrons located? How will you show this in your model?
- How will you tell the difference between protons, neutrons and electrons? You could create a key that tells viewers how each particle is represented in your model.

▼ TABLE 14.6.1 The first 18 elements

Element	Number of protons	Number of neutrons	Number of electrons
Hydrogen	1	0	1
Helium	2	2	2
Lithium	3	4	3
Beryllium	4	5	4
Boron	5	6	5
Carbon	6	6	6
Nitrogen	7	7	7
Oxygen	8	8	8
Fluorine	9	10	9
Neon	10	10	10
Sodium	11	12	11
Magnesium	12	12	12
Aluminium	13	14	13
Silicon	14	14	14
Phosphorus	15	16	15
Sulfur	16	16	16
Chlorine	17	18	17
Argon	18	22	18

ANALYSIS

- Line your models up in a single line. Describe any repeating patterns you see.
- Line your models up so they look like the periodic table arrangement. Does this make it easier to see any repeating patterns? Describe any repeating patterns you didn't see from question 1.
- Describe how the size of the nucleus changes as you go from element 1 (hydrogen) to element 18 (argon). Explain the reason this trend occurs.
- Describe and explain at least two other trends you see in your models as you go from element 1 (hydrogen) to element 18 (argon).

DATA SCIENCE



Learn more about analysing trends in data in **Module 2.8**.

14.7 Properties of elements

BY THE END OF THIS MODULE YOU WILL BE ABLE TO:

- ✓ predict properties of elements based on their position in the periodic table
- ✓ describe physical properties of metals, non-metals and metalloids.



Video activity
Noble gases

Interactive resource
Drag and drop: Properties of elements

Extra science investigation
Comparing properties

GET THINKING

There are more than 100 elements on the periodic table. It would be almost impossible to remember all the properties of the individual elements. The periodic table allows us to predict properties of an element based on the location of the element in the table. Can you think of any other examples in science or your everyday life where a table, key or image can be used to predict information?

Properties of elements and the periodic table

As we saw in Figure 14.3.2, the periodic table is often colour-coded to show the three classifications of all elements: metals, non-metals and metalloids.

Most of the elements on the periodic table are solids. This includes most of the metals, except for mercury, which is a liquid at room temperature. Most of the non-metals are gases; one is a liquid (bromine), and some are solids (such as carbon and phosphorus).

The properties of each element determine where the element falls within these three categories. The general properties of elements in each of the three classifications – metals, non-metals and metalloids – are shown in Table 14.7.1.

▼ TABLE 14.7.1 Classifications of all elements on the periodic table, and their general properties

	Metals	Non-metals	Metalloids
Physical properties	<ul style="list-style-type: none"> • Shiny, metallic lustre • Solid at room temperature • Good conductors of heat and electricity • Malleable • Ductile • High melting points 	<ul style="list-style-type: none"> • Dull • Poor conductors of heat and electricity • Brittle • Low melting points 	<ul style="list-style-type: none"> • Have some properties of both metals and non-metals
Examples	 <p>Iron</p>  <p>Aluminium</p>  <p>Gold</p>	 <p>Chlorine</p>  <p>Sulfur</p>  <p>Carbon</p>	 <p>Boron</p>  <p>Germanium</p>  <p>Arsenic</p>

Properties of metals

Most elements on the periodic table are metals, as seen in Figure 14.3.2 (p. 489). Metals have a set of common properties that make them useful.

We describe metals as **lustrous**, which means when you cut or polish them, they are shiny (Figure 14.7.1). We use this property of metals in jewellery and metal plating to make an object shiny. Another useful property of metals is the ability to conduct heat and electricity. We use this property when we make electrical wiring and saucepans for cooking.

All metals can have their shape changed; we call this malleability (being **malleable**). They can also be stretched into a wire: they are **ductile**. We use these properties of metals when we make such things as building materials, containers, wiring and vehicle parts. Metals have a range of melting points, but they are generally high, which means we can use metals for applications that require an object to be stable at high temperatures, such as cooking pans.



▲ FIGURE 14.7.1 A useful property of metals is lustre.

lustrous

shiny when cut or polished

malleable

able to be beaten into different shapes

ductile

able to be stretched into a wire

Properties of non-metals

Figure 14.3.2 shows there are fewer non-metals than there are metals. Non-metals are not good conductors of heat and electricity and they have low melting points. Many non-metals are gases, some are solids, and some are liquids at room temperature, making them useful in a range of applications. We use helium to fill balloons, neon to make bright advertising signs (Figure 14.7.2), and chlorine to clean and treat swimming pools.

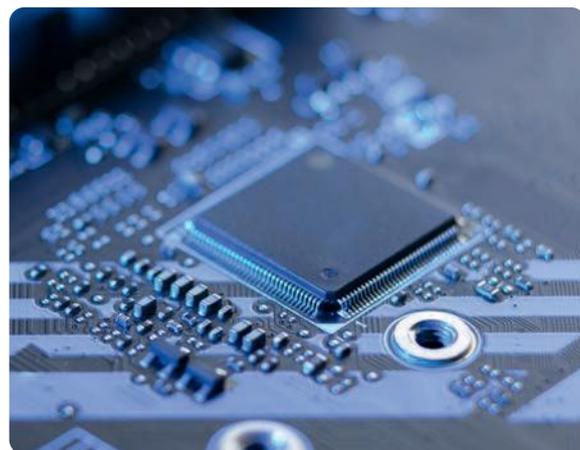
Properties of metalloids

There are not many metalloids. One of the best known is silicon, which can conduct electricity like a metal, but is brittle like a non-metal. We use silicon in computer chips because it has excellent electrical conductivity (Figure 14.7.3).

Iana Surman/Shutterstock.com



▲ FIGURE 14.7.2 Neon is a non-metal gas used in signs and decorations.



▲ FIGURE 14.7.3 Silicon chips are used in computing applications

Andrii Zaistrozhnov/Dreamstime LLC

Groups of the periodic table

The broad categories of metals, non-metals and metalloids each include a wide range of elements. The periodic table allows us to further break down the metals into different metal groups, each of which has their own properties. The same applies to the non-metals. You can think of these groups as the sub-groups of metals or non-metals.

The vertical groups of the periodic table are often given names that represent their common properties. The way the periodic table is organised means that elements in the same group behave in a similar way in chemical reactions. They also have similar physical properties, such as electrical conductivity or hardness. Therefore, we can use the periodic table to predict information about elements based on where they are on the table (Table 14.7.2).

Hydrogen is the one element that does not really fit these trends. Although it is in group 1, hydrogen does not have the same properties as other group 1 elements.

▼ TABLE 14.7.2 Groups of the periodic table

Group	Name	Common examples	Properties
1	Alkali metals	Sodium, potassium	<ul style="list-style-type: none">• Low-density metals• Highly reactive
2	Alkali earth metals	Magnesium, calcium	<ul style="list-style-type: none">• Low-density, silvery metals• Quite reactive
3–12	Transition metals	Copper, nickel, zinc	<ul style="list-style-type: none">• High-density metals• Mildly–lowly reactive
17	Halogens	Fluorine, chlorine	<ul style="list-style-type: none">• Toxic substances• Highly reactive
18	Noble gases	Helium, neon, xenon	<ul style="list-style-type: none">• Gases• Very unreactive

Properties of groups 1 and 2 metals

alkali metals

group 1 metals on the periodic table; they are highly reactive

Group 1 elements, the **alkali metals**, are metals that have vigorous or explosive reactions with water and oxygen. Figure 14.7.4 shows the fizzing and sparking that occurs when you add potassium to water. Some of the group 1 elements need to be stored in oil or in containers with the air removed to prevent them from reacting explosively when not being used. This is because they react with the water vapour in the air.

alkali earth metals

group 2 metals on the periodic table; they are quite reactive

Group 2 elements, the **alkali earth metals**, are still quite reactive, but not as reactive as group 1 elements. The group 2 elements do react with water, but slowly. Some of these elements need heat to start a reaction with water or air.



▲ FIGURE 14.7.4 Potassium reacts explosively with water.

Charles D. Winters/Science Source/Science Photo Library

Properties of halogens and noble gases

The **halogens** are the group 17 elements. They include chlorine, bromine and fluorine. All halogens are very reactive. All halogens will form acids when dissolved in water.

The elements in group 18, the **noble gases**, are very stable and very unreactive. The noble gases do not mix (or react) with other elements. To remember this you could use the idea ‘nobles don’t mix with others’.

halogen

an element in group 17 on the periodic table

noble gases

an element in group 18 on the periodic table

☆ ACTIVITY

Creating your own periodic table summary

You will need a blank periodic table. It may have element names and symbols, but no other information should be present. Your teacher may provide one for you or you can find a blank copy on the internet. You will need some coloured pencils, textas or highlighters.

- 1 Label groups 1–18.
- 2 Identify and label each group that has a name.
- 3 Label rows 1–7.
- 4 Use three colours to shade the metals, metalloids and non-metals. Create a key so you know which colour represents which type of element.

14.7 LEARNING CHECK

- 1 **Describe** where you would find the metals, non-metals and metalloids on the periodic table.
- 2 **Explain** what elements in the same group on the periodic table have in common.
- 3 Use the information in this chapter to **match** the elemental properties (a–f) to their correct chemical name and symbol (i–vi) in the list below. You may also need to do some extra research.

Elemental properties

- a I am shiny and gold in colour. I conduct heat and electricity and am malleable. I am prized for my beauty.
- b I am a gas, yellow in colour. I do not conduct electricity. I am commonly used in swimming pools as a disinfectant.
- c I am shiny silver in colour and am one of the lighter elements of my kind. I conduct electricity and am malleable. I am used in soft drink cans and can be recycled.
- d I am a colourless gas that makes up most of the air you breathe, and I am not oxygen.
- e I am soft and white with a silvery lustre. I conduct electricity and am malleable. I ignite with a purple flame when mixed with water.
- f I am a colourless, odourless inert gas but, when in a vacuum, I change to reddish-orange. Because of this I am often used in colourful electric signs.

Chemical name and symbol

- i chlorine, Cl
- ii potassium, K
- iii gold, Au
- iv neon, Ne
- v aluminium, Al
- vi nitrogen, N

- 4 From what you know about hydrogen, **explain** why it doesn’t fit into group 1 in terms of its properties.



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ presenting data in appropriate tables
- ▶ conducting tests to investigate the properties of metals and non-metals.

Scientific data is collected in experiments. To make the best use of this information, it should be presented in a clear, logical and organised way, such as in a table.

You will have constructed tables for previous experiments and will be familiar with using a title, column and row headings, and ruled lines. Apart from this basic structure, what else can you do to make your table useful and readable?

- Table layout: Consider how many columns and rows you need and how wide your columns will be. Generally, you should have more rows than columns, so you don't have

thin columns containing text that is difficult to read. Plan your table before you start.

- Column labelling: Label columns clearly. 'Trial 1' is not a useful column heading. Try to incorporate what you are measuring; for example, 'concentration of acid' or 'mass of products'.

You should construct your tables before conducting your experiment, so you know exactly what data to measure, with units in header rows. Alternatively, you could use a spreadsheet program such as Excel to construct tables and collect your data.

▼ TABLE 14.8.1 A poorly constructed table. Rows and columns are not considered, and column headings are not useful if you are not familiar with the experiment

50 g trial 1	50 g trial 2	50 g trial 3	100 g trial 1	100 g trial 2	100 g trial 3	150 g trial 1	150 g trial 2	150 g trial 3

▼ TABLE 14.8.2 A well-constructed table. Rows and columns have clear headings. Trials and measures of the independent variable are separated

Mass of calcium carbonate added to hydrochloric acid (g)	Time taken for reaction to complete (s)		
	Trial 1	Trial 2	Trial 3
50			
100			
150			



Video
Science skills in a minute: Presenting data in tables

Science skills resource
Science skills in practice: Data tables

EXPERIMENT 1: IDENTIFYING METAL AND NON-METAL ELEMENTS

AIM

To conduct tests to identify some metal elements and a non-metal element

MATERIALS AND EQUIPMENT

For Part A: Identifying metals – flame test

- fine-mist spray bottles containing solutions of barium chloride, calcium chloride, copper chloride, copper sulfate, lithium chloride, potassium chloride, sodium chloride and strontium chloride
- Bunsen burner
- heatproof mat
- matches
- PPE equipment
- safety goggles

For Part B: Identifying non-metals – hydrogen pop test

- 2 large test tubes
- test-tube holder
- 5 cm magnesium ribbon
- 20 mL of 1.0 mol/L hydrochloric acid
- matches
- PPE equipment
- safety goggles

Safety

Flame test: when spraying chemicals, ensure you do not point the bottle at other people. Spray small puffs, and wipe down all benches and equipment in the area when you finish the experiment.

Hydrogen pop test: use appropriate PPE when handling hydrochloric acid. Wash your hands immediately if you come into contact with the acid. The hydrogen gas produced is flammable. Use matches only to ignite the hydrogen gas and point the test tube away from people when igniting the gas.

PROCEDURE

PART A: IDENTIFYING METALS – FLAME TEST

- 1 Place the Bunsen burner on a heatproof mat and light it. Set to a blue flame.
- 2 Select a spray bottle and spray a small puff of the chemical into the flame horizontally and observe the colour of the flame.
- 3 Swap with your partner and repeat step 2 to confirm the colour of the flame.
- 4 Repeat steps 2–3 for all the spray bottle solutions.
- 5 Record all observations in a suitable table.

PART B: IDENTIFYING NON-METALS – HYDROGEN POP TEST

- 1 Place one large test tube into the test-tube holder.
- 2 Add the magnesium ribbon into the test tube.
- 3 Add the hydrochloric acid to the test tube.
- 4 Immediately turn the second test tube upside down and hold it over the mouth of the first test tube to capture the gas.
- 5 After about a minute, light a match.
- 6 Lift the second test tube away, keeping it upside down. Hold the lit match to the bottom of the test tube and you should hear a pop as the hydrogen gas ignites. If you do not get a pop, replace the test tube over the first test tube for another minute to collect more gas.
- 7 Record all observations in a suitable table.

RESULTS

Create tables for both investigations to accurately record your data.

ANALYSIS

- When you spray metals in solution into a hot flame, they give a characteristic colour. This means that the same element will always give the same colour. Use Table 14.8.3 to help identify the metals in the spray bottle solutions.

▼ TABLE 14.8.3 Colour of metals in a flame test

Metal	Colour
Barium	Yellow-green
Copper	Green
Potassium	Purple
Strontium	Red
Calcium	Orange-red
Lithium	Red
Sodium	Orange

- Describe any issues you had with identifying the elements. Were some easier to identify than others? Why?
- Describe the observations you made during the pop test.

EXPERIMENT 2: INVESTIGATING THE PROPERTIES OF ELEMENTS

AIM

To investigate the properties of a range of metal and non-metal elements

MATERIALS AND EQUIPMENT

- pieces of various metals – copper, iron, aluminium, zinc
- sample of a non-metal – sulfur (your teacher might demonstrate this element for you due to the risks involved with handling sulfur)
- power pack
- connecting leads
- ammeter or light globe
- sandpaper
- hammer or mallet

 **Safety**

Sulfur can be dangerous to handle in solid form as it is a fine powder that is easy to inhale. Your teacher might demonstrate this element for you.

PROCEDURE

- 1 Collect the samples of elements from your teacher (they may differ from those listed above). Record what elements you are using in a results table.
- 2 Record the state (solid, liquid, gas) and describe the appearance of the element.
- 3 Set up a conductivity testing station, as shown in Figure 14.8.1. Test each element for conductivity. If the globe lights up or the ammeter registers a current, then the substance conducts electricity.
- 4 Polish each element using sandpaper if possible. Record whether the element is lustrous or dull.
- 5 Try to bend each element. Record whether it is malleable or not.

RESULTS

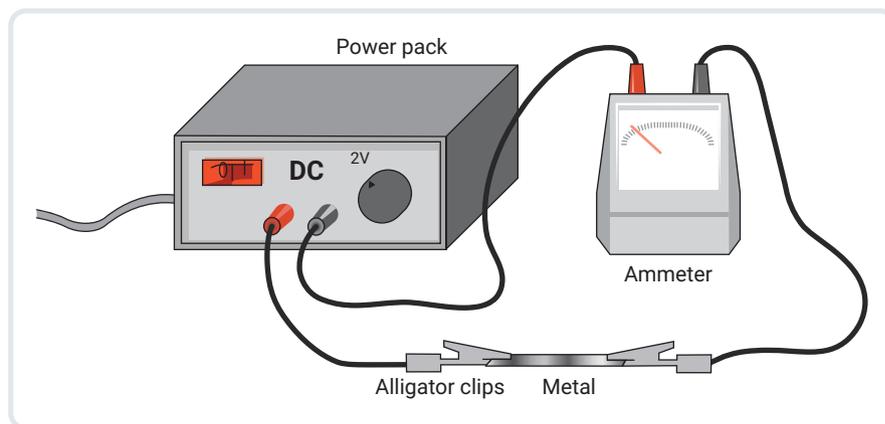
Construct a results table to show the outcome of the range of tests on the different elements.

ANALYSIS

- 1 Did all the elements give the expected results? Describe any that didn't and suggest reasons for this occurring.
- 2 Discuss why it is more difficult to conduct these tests on non-metal elements.
- 3 Explain why we did not test the metals for melting point?
- 4 There are not a lot of metalloid elements available to test in experiments like this. If you were given a metalloid, describe what you might expect to observe during the tests conducted in this experiment.

CONCLUSION

Write a conclusion summarising the properties of the types of elements you tested.



▲ **FIGURE 14.8.1** The equipment needed for testing conductivity. You can substitute the ammeter for a light globe, which will light up if the substance conducts electricity.

14.9 Molecules and compounds

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ distinguish between elements, compounds and molecules
- ✓ list known monatomic and diatomic elements.



Video activity
Elements and compounds

Interactive resource
Label: Molecule or compound?

Extra science investigation
Observing elements and compounds

GET THINKING

A large part of chemistry relies on the study of atoms connecting, or chemically bonding. Think of one of your favourite objects. Whether it is an electronic device or something simple such as a netball, it was probably made by combining materials made from different elements and compounds.

What is a molecule?

Water is a common **molecule**. Water is made of two hydrogen atoms and one oxygen atom: H_2O . Looking at a periodic table (Figure 14.3.2, p. 489), what do you notice about the atoms in a water molecule? Both hydrogen and oxygen are non-metals. A molecule is the structure that forms when a group of two or more non-metal atoms are held together by a **chemical bond**.

The molecules shown in Table 14.9.1 represent two types of molecules. If all the atoms in the molecule are the same – such as ozone, O_3 , which is three oxygen atoms – then it is called a **molecule of an element**. If two or more different types of non-metal atoms are bonded together – such as water, H_2O – then it is called a **molecule of a compound**, or, more commonly, a molecular compound. In summary, for a substance to claim fame as a molecule, the general rule is that it is made entirely of non-metal atoms!

molecule

two or more non-metal atoms bonded together

chemical bond

a force that holds atoms together

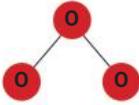
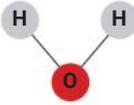
molecule of an element

a molecule in which two or more atoms of the same non-metal element are chemically bonded together

molecule of a compound

a molecule in which two or more atoms of different non-metal elements are chemically bonded together; also known as a molecular compound

▼ TABLE 14.9.1 Comparing a molecule of an element to a molecule of a compound

	Molecule of an element	Molecule of a compound
Types of atoms	<ul style="list-style-type: none"> • Atoms are identical. • Atoms are non-metals. 	<ul style="list-style-type: none"> • Atoms are different. • Atoms are non-metals.
3D model	 <p>Ozone, O_3</p>	 <p>Water, H_2O</p>
2D model	 <p>Ozone, O_3</p>	 <p>Water, H_2O</p>

What is a compound?

A **compound** is a substance made up of two or more different types of atoms chemically bonded together. Similar to molecules, there are two types of compounds, and, generally, the type is determined by the bond between the atoms, and whether the bonded atoms are metals or non-metals.

Molecular compound

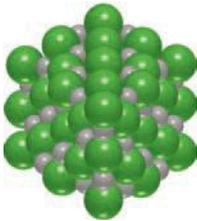
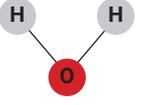
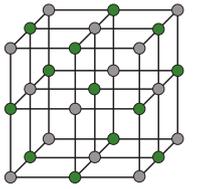
The first type of compound is a **molecular compound** – a compound formed between two different types of non-metal atoms. Water is a molecular compound made up of the non-metals hydrogen and oxygen.

Ionic compound

The second type of compound is an **ionic compound** – a compound formed when the two different atoms are a metal and a non-metal. Table salt (sodium chloride, NaCl), is an example of an ionic compound made up of the metal sodium and the non-metal chlorine.

Table 14.9.2 compares molecular and ionic compounds.

▼ TABLE 14.9.2 Comparing a molecular compound to an ionic compound

	Molecular compound	Ionic compound
Types of atoms	<ul style="list-style-type: none"> • Atoms are different. • Atoms are non-metals. 	<ul style="list-style-type: none"> • Atoms are different. • Atoms are metals and non-metals.
3D model	 <p>Water, H₂O</p>	 <p>Salt, NaCl</p>
2D model	 <p>Water, H₂O</p>	 <p>Salt, NaCl</p>

compound

a chemical substance made up of two or more different atoms chemically bonded together; bonded atoms can be a metal and a non-metal (ionic compound), or two non-metals (molecular compound)

molecular compound

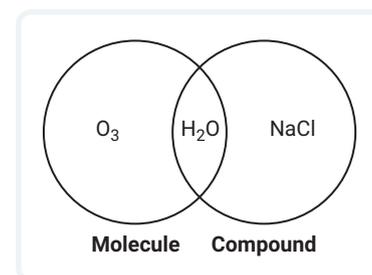
a compound formed when two different non-metals chemically bond

ionic compound

a compound formed when a metal and a non-metal chemically bond

Molecule or compound?

Sometimes a visual representation, or a model, can be useful in understanding an idea. Figure 14.9.1 shows how compounds and molecules relate to one another in a Venn diagram. This figure shows water, H₂O, in the overlapping area, which means it is both a molecule and a compound. Ozone, O₃, is only a molecule. Salt, NaCl, is only a compound. More specifically, we learned it is an ionic compound, since it is made of a metal (sodium, Na) bonded to a non-metal (chlorine, Cl).



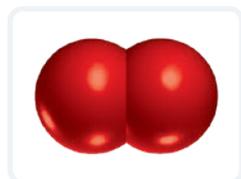
▲ FIGURE 14.9.1 The relationship between compounds and molecules

Diatomic and monatomic elements

Figure 14.9.2 shows a molecule of oxygen gas. Single oxygen atoms do not exist for very long on their own in nature. Instead, they 'pair up'. A molecule of oxygen gas is always made up of two oxygen atoms chemically bonded together. Oxygen is therefore **diatomic**, meaning it consists of two atoms. The chemical formula for oxygen gas is O_2 , where the subscript '2' means there are two oxygen atoms. Note that every molecule that consists of two atoms is diatomic.

diatomic

describes a molecule consisting of two atoms (*di* means 'two'; *atomic* means 'atom')



▲ **FIGURE 14.9.2**
Oxygen, an example of a diatomic molecule and an element

Diatomic elements include oxygen (O_2), iodine (I_2), bromine (Br_2), chlorine (Cl_2), fluorine (F_2), nitrogen (N_2) and hydrogen (H_2).

Can you think of a mnemonic phrase to help you remember the diatomic elements?

I	→	Iodine, I_2
Bring	→	Bromine, Br_2
Cookies	→	Chlorine, Cl_2
For	→	Fluorine, F_2
Our	→	Oxygen, O_2
New	→	Nitrogen, N_2
Home	→	Hydrogen, H_2

Rarely, some atoms exist on their own in their natural state. These are known as **monatomic** (or **monoatomic**) elements. Only six of the 92 naturally occurring elements are monatomic: helium (He), neon (Ne), argon (Ar), krypton (Kr), xenon (Xe) and radon (Rn). Do you notice anything about the placement on the periodic table of all of these monatomic elements? They are all in the last group; they are known as noble gases because they are stable and unreactive.

monatomic/monoatomic

an element consisting of just one atom (*mono* means 'one'; *atomic* means 'atom')



Bro Crock/Shutterstock.com



sukrat13/Shutterstock.com



Mrs_ya/Shutterstock.com

▲ **FIGURE 14.9.3** Monatomic elements in everyday life: (a) neon lights; (b) helium balloons; (c) argon (in lightbulbs)

14.9 LEARNING CHECK

14.9

- 1 a Using the diagram below, begin at the Start (S square at top left) position and move to the End (E square at bottom right) position by identifying and alternating between diatomic and monatomic elements only. You can move in any direction.

S	H ₂	Kr	N ₂	Ne	Al	He	F ₂	He	O ₂	Po
Li	Be	Y	S	O ₂	Ga	Br ₂	Na	C	Rn	Sr
He	I ₂	Ar	Cl ₂	Rn	As	Rn	Rb	Sc	Br ₂	Mn
Br ₂	Te	K	Mg	Cs	Sn	N ₂	Te	Ti	Kr	Cu
Xe	F ₂	He	Br ₂	Ne	O ₂	He	Ba	Fe	H ₂	E

- b Copy the frequency table into your notebook and **complete** the tally and total columns for monatomic and diatomic elements as you move through the diagram in part a.

Frequency table: Monatomic and diatomic elements

Monatomic elements			
Symbol	Atom this represents	Tally	Total
Ar	argon		
He	helium		
Ne	neon		
Kr	krypton		
Rn	radon		
Xe	xenon		
Diatomic elements			
Symbol	Atom this represents	Tally	Total
Br ₂	bromine		
Cl ₂	chlorine		
F ₂	fluorine		
H ₂	hydrogen		
I ₂	iodine		
N ₂	nitrogen		
O ₂	oxygen		

- c **Create** a column graph to represent the data in your frequency table.
- 2 **Identify** whether the following arrangements exist. If they do exist, **provide** an example.
- | | |
|-------------------------|-------------------------|
| a An atom of a compound | b Molecules of elements |
| c A molecular compound | d Atoms of elements |
- 3 **Explain** the difference between elements and compounds. **Include** a diagram in your answer.

14.10 Models and chemical formulas

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ create both 2D and 3D models of atoms, elements or compounds
- ✓ interpret chemical formulas for meaning.



Interactive resource
Simulation: Build a molecule

Extra science investigation
Modelling elements and compounds

GET THINKING

Models and representations in science are needed to communicate ideas, inform, raise awareness and increase the sense of wonder in science. Think about ways that scientific knowledge is all around you – when you turn on the TV, cook food or even ride your bicycle.

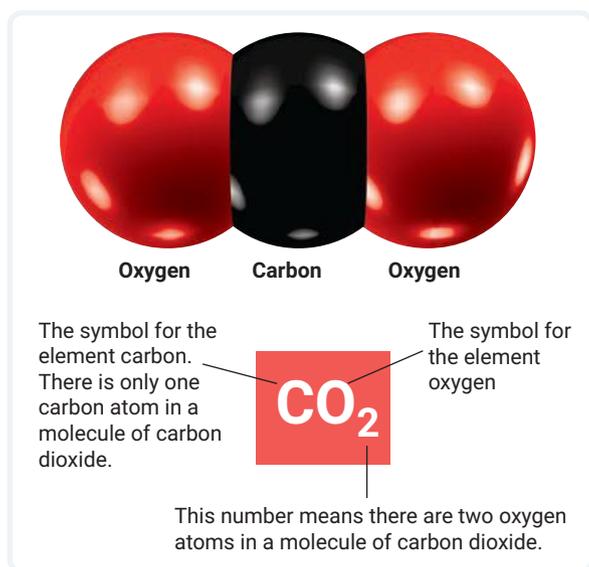
Representations of elements and compounds

There are several ways that chemists represent elements and compounds, depending on the purpose or reason for that representation.

Chemical formulas

In Module 14.9, you saw diatomic oxygen written as O_2 , where the '2' referred to two oxygen atoms. In instances where there are numerical subscripts in compounds or molecules, the letters representing the elements are no longer referred to as chemical symbols but are instead part of a **chemical formula**. Scientists use chemical formulas when there is more than one atom in a substance; the formula gives the elemental composition of molecules. It's similar to a recipe for cooking. The formula, or recipe, consists of the chemical symbol for the element, followed by a subscript that tells you the number of atoms present.

Let's look at the formula for a molecule of carbon dioxide as an example (Figure 14.10.1). The chemical formula is CO_2 . There is no subscript for carbon, which means there is only one carbon atom. The subscript is written only if the number of atoms is greater than one. However, the oxygen has a '2' subscript, which means there are two oxygen atoms present. This molecule contains one carbon and two oxygen atoms; the ratio of carbon atoms to oxygen atoms is 1:2. Some other examples are shown in Table 14.10.1.



▲ **FIGURE 14.10.1** A carbon dioxide molecule and the chemical formula for carbon dioxide

3D models

We have seen that chemical formulas provide some information about the composition of the chemical substance. However, the chemical formula does not give information about the structure of the chemical substance – that is, how the atoms are joined together.

Your teacher may have several ball-and-stick model kits, which can be used as a continuation of the idea of atoms represented as spheres. These kits allow you to see compounds in three dimensions, which is how the compounds exist in the real world.

▼ TABLE 14.10.1 The chemical formulas of some common chemicals

Name	Chemical formula	Ratio
Water	H ₂ O	2 atoms of hydrogen and 1 atom of oxygen
Carbon dioxide	CO ₂	1 atom of carbon and 2 atoms of oxygen
Oxygen	O ₂	2 atoms of oxygen
Methane	CH ₄	1 atom of carbon and 4 atoms of hydrogen
Ammonia	NH ₃	1 atom of nitrogen and 3 atoms of hydrogen
Sodium chloride	NaCl	1 atom of sodium and 1 atom of chlorine

The spheres, or balls, in a 3D model represent the atoms, and each type of atom is represented by a different colour. The connection, or bond, that holds the atoms together is represented by the stick. These models not only show the compounds as they are arranged in space (given that they are too small to see in real life), but they also provide hands-on experience for learners of chemistry. Study the ball-and-stick models of water and ethanol in Figure 14.10.2.

Structural formulas

A **structural formula** is a two-dimensional representation of a molecule that gives us information about which atoms are bonded to each other (Figure 14.10.3). Chemists also build 3D models of structural formulas, usually with a computer simulation. The 3D shape provides information about how compounds behave physically and chemically, which is particularly important in fields such as medicine.

14.10 LEARNING CHECK

- Explain** how subscripts are used to indicate the number of atoms present in a chemical formula.
- Explain** what is meant by the statement 'a chemical formula represents the ratio between atoms'.
- Compare** chemical formula to structural formula.
- Determine** the missing ratio or chemical formula for positions a–e in the table below. The first row has been done for you.

Name	Ratio of elements	Chemical formula
Lithium carbonate	lithium : carbon : oxygen = 2:1:3	Li ₂ CO ₃
Phosphorus trichloride	phosphorus : chlorine = 1:3	a
Silicon dioxide	silicon : oxygen = 1:2	b
Nitrogen dioxide	c	NO ₂
Carbon tetrachloride	carbon : chlorine = 1:4	d
Sulfur trioxide	e	SO ₃

DATA SCIENCE



Learn more about scientific models in **Module 2.9**.



Water, H₂O

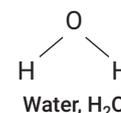


Ethanol, C₂H₅OH

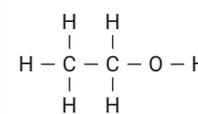
▲ FIGURE 14.10.2 Ball-and-stick models of water and ethanol

structural formula

a graphic representation that shows the arrangement of atoms in a molecule or compound



Water, H₂O



Ethanol, C₂H₅OH

▲ FIGURE 14.10.3 Structural formulas of water and ethanol

14.11 Periodic table development

BY THE END OF
THIS MODULE, YOU
WILL BE ABLE TO:

- ✓ describe how the first periodic table was developed by Mendeleev
- ✓ describe how the periodic table has been improved over time as science has progressed and new elements have been discovered.



Video activity
Mendeleev and the
periodic table

Early attempts at organising elements

A number of scientists, including Antoine Lavoisier and Johann Dobereiner, proposed methods of grouping elements into an organised structure, but none managed to organise all the elements that were known.

John Newlands was a British chemist who noticed that there was a pattern of properties repeating about every eight elements. He called this the law of octaves. He arranged elements into groups of eight elements, as seen in Table 14.11.1. You may notice that not all elements are present on his table. The flaw in his proposal was that he left no gaps for undiscovered elements. As not all elements were known at this time, when new elements were discovered, his table was no longer accurate.

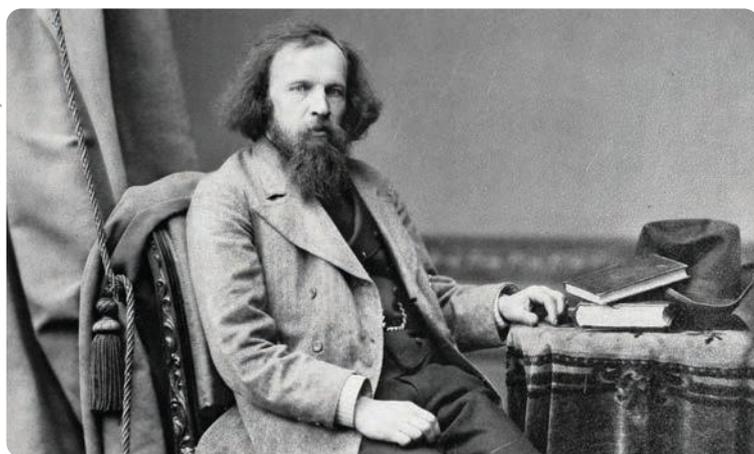
▼ TABLE 14.11.1 Newland's law of octaves

Octave 1	H	Li	Be	B	C	N	O
Octave 2	F	Na	Mg	Al	Si	P	S
Octave 3	Cl	K	Ca	Cr	Ti	Mn	Fe
Octave 4	Co, Ni	Cu	Zn	Y	In	As	Se
Octave 5	Br	Rb	Sr	Ce, La	Zr	Di, Mo	Ro, Ru
Octave 6	Pd	Ag	Cd	U	Sn	Sb	I
Octave 7	Te	Cs	Ba, V	Ta	W	Nb	Au
Octave 8	Pt, Ir	Os	Hg	Tl	Pb	Bi	Th

Mendeleev's periodic table

In 1869, Dmitri Mendeleev proposed the periodic table seen in Figure 14.11.2. He arranged the elements in order of atomic weight and used Newland's idea of properties that would repeat after a certain number of elements. He found that the patterns were not perfect and left spaces on his table, proposing that elements not yet known would fill the gaps.

Pictorial Press Ltd./Alamy Stock Photo



▲ FIGURE 14.11.1 Dmitri Mendeleev

I H 1.01										
	II	III	IV	V	VI	VII				
Li 6.94	Be 9.01	B 10.8	C 12.0	N 14.0	O 16.0	F 19.0				
Na 23.0	Mg 24.3	Al 27.0	Si 28.1	P 31.0	S 32.1	Cl 35.5				
							VIII			
K 39.1	Ca 40.1		Ti 47.9	V 50.9	Cr 52.0	Mn 54.9	Fe 55.9	Co 58.9	Ni 58.7	
Cu 63.5	Zn 65.4			As 74.9	Se 79.0	Br 79.9				
Rb 85.5	Sr 87.6	Y 88.9	Zr 91.2	Nb 92.9	Mo 95.9		Ru 101	Rh 103	Pd 106	
Ag 108	Cd 112	In 115	Sn 119	Sb 122	Te 128	I 127				
Ce 133	Ba 137	La 139		Ta 181	W 184		Os 194	Ir 192	Pt 195	
Au 197	Hg 201	Tl 204	Pb 207	Bi 209						
			Th 232		U 238					

▲ FIGURE 14.11.2 Mendeleev's first periodic table (1869)

Mendeleev predicted the properties of these missing elements. One such element was gallium. He was able to predict its properties accurately based on its position in his periodic table.

Over time, the Mendeleev model was refined and adjusted as more elements were discovered. In the time of Mendeleev, only 63 elements were known. Now we know 118 elements with more elements constantly being created by scientists in laboratories.

14.11 LEARNING CHECK

- 1 Describe** why Mendeleev's periodic table was a better proposal than Newland's periodic table.
- 2 Research** the work of Johann Dobereiner. **Describe** the 'triads' he observed in elements.

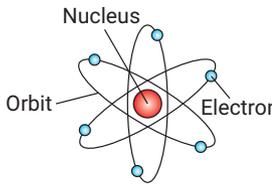
14 REVIEW

REMEMBERING

- 1 **Recall** the term given to the smallest unit of matter.
- 2 **Describe** the difference between an atom of an element and a molecule of an element. Use examples to support your answer.
- 3 **List** the 13 monatomic and diatomic elements.
- 4 How many electrons fit into the third electron shell?
- 5 **Recall** how Dmitri Mendeleev organised his first periodic table.

UNDERSTANDING

- 6 **Explain** the difference between a molecular compound and an ionic compound.
- 7 The names of the elements calcium and carbon both begin with the letter 'C.' **Explain** why the chemical symbol for both is not simply 'C'.
- 8 What is the electron configuration of:
 - a hydrogen?
 - b calcium?
 - c phosphorus?
- 9 **Complete** the table at the top of the next column to summarise the different atomic models.

Scientist	Diagram of atomic model	Summary of model
Dalton		Negatively charged particles in a sphere of positive charge
		
Bohr		

- 10 **Explain** how Thomson confirmed the existence of subatomic particles in the atom.

APPLYING

- 11 **Identify** and count the number of atoms in each compound in the table at the bottom of the page. **Identify** each as a molecular compound or an ionic compound. The first row has been completed for you.
- 12 Which element is represented on the periodic table by the following locations?
 - a Period 2, group 14
 - b Period 3, group 16
 - c Group 15, period 6
- 13 **Describe** a use of metals where the property of malleability would be required.

	Chemical formula	Number and type of each atom	1st element	2nd element	3rd element	Molecular or ionic compound?
a	NBr ₃	N = nitrogen: 1 Br = bromine: 3	Non-metal	Non-metal	-	Molecular
b	CH ₄ O					
c	NaNO ₃					
d	H ₂ SO ₄					

ANALYSING

- 14 The table below shows properties of common elements at 20°C. Use this table to answer the following questions.
- Determine the chemical symbol for beryllium.
 - Identify elements that have a density of more than 3.5 g/cm³.
 - Does germanium have an atomic weight more than or less than that of chromium?

Element	Symbol	Atomic weight (atomic mass units)	Density (g/cm ³)
Beryllium	Be	9.012	1.85
Bromine	Br	79.90	3.10
Cadmium	Cd	112.41	8.65
Carbon	C	12.011	2.25
Chromium	Cr	52.00	7.19
Cobalt	Co	58.93	8.90
Copper	Cu	65.55	8.94
Germanium	Ge	72.59	5.32

- 15 Sodium metal must be stored in oil for it to be safe. Magnesium metal can be stored in air. Explain why there is a difference between the two metals.

EVALUATING

- 16 The table above right shows some properties of four metals.
- Justify why metal A is used to build aeroplanes.
 - Predict and explain whether metal B or C would be better for electrical wiring.
 - Metal D is used for construction in high-rise buildings. What other properties would be important for this metal to have?

Metal	Melting point	Electrical conductivity	Density
A	Medium	Low	Low
B	High	High	Low
C	Low	High	Low
D	Low	Low	High

CREATING

- 17 Use the key below to complete the missing sections of the table that follows.

Key of atom types

- oxygen (O)
- nitrogen (N)
- chlorine (Cl)
- hydrogen (H)
- carbon (C)
- aluminium (Al)

Metal	Chemical formula	Structural formula
a		
b	CO ₂	
c		
d	AlCl ₃	
e		

SCIENCE IN DEPTH STUDY

#14

1 Connect what you've learned

Explain how an element differs from a compound and a mixture. Create a mind map to show how atoms, molecules, compounds and elements are connected to each other.



2 Check your thinking

In groups, discuss why not all elements exist in elemental form in nature. Present your suggestions to the class. You could do some research to determine which group was closest to the true reason.



3 Get into action

Choose an element that is used in everyday life. Do some research into its properties, where we obtain it, and its uses.



4 Communicate

Create an infographic to educate people about the uses and importance of the element you chose to research.

CHANGE

SYLLABUS OUTCOMES

A STUDENT:

- ▶ explains how energy causes geological and chemical change SC4-CHG-01
- ▶ uses scientific tools and instruments for observations SC4-WS-01
- ▶ plans safe and valid investigations SC4-WS-03
- ▶ follows a planned procedure to undertake safe and valid investigations SC4-WS-04

CHAPTERS RELATED TO THIS FOCUS AREA ARE:

- ▶ **CHAPTER 15** – ENERGY TRANSFERS
- ▶ **CHAPTER 16** – CHEMICAL CHANGE
- ▶ **CHAPTER 17** – PLATE TECTONICS
- ▶ **CHAPTER 18** – THE ROCK CYCLE

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15

Energy transfers

15.1 Kinetic energy (p. 524)

A mass in motion has kinetic energy.

15.2 Potential energy (p. 527)

Potential energy is stored energy that is ready to do work.

15.3 Open and closed systems (p. 530)

Energy and matter are transferred into and out of open systems but only energy is transferred into and out of closed systems.

15.4 Energy transfer (p. 532)

Energy transfer is the movement of a single type of energy from one place to another or from one body to another.

15.5 WORKING SCIENTIFICALLY: Conducting risk assessments (p. 536)

Measuring heat transfer

15.6 Conduction, convection and radiation (p. 538)

Heat can be transferred in three ways: conduction, convection and radiation.

15.7 Energy transformation (p. 540)

Energy transformation is changing energy from one type into another.

15.8 WORKING SCIENTIFICALLY: Modelling energy transfers and transformations (p. 544)

Modelling energy transfers and transformations with flow charts

15.9 ABORIGINAL AND TORRES STRAIT ISLANDER SCIENCE CONTEXTS: Traditional fire-making techniques (p. 546)

Aboriginal and Torres Strait Islander Peoples used their knowledge of energy transfer and friction to develop methods for making fire.

15.10 SCIENCE IN CONTEXT: Geothermal energy for electricity generation (p. 549)

Geothermal energy is heat trapped in rocks within Earth's crust and is a source of electricity in some countries.



Jonathan Knowles/Getty Images

▲ FIGURE 15.01 An example of a Rube Goldberg machine

A Rube Goldberg machine is a machine that uses many energy transfers and transformations to complete a simple task in a complicated way. Energy is a basic idea in science, but what is energy? How is energy defined? What is an energy transfer or transformation? Why are they important?

- Think about your lifestyle. What types of energy do you use every day?

#15 DIVE INTO SCIENCE!

At the end of this chapter, you can complete Science in Depth Study #15. You can use the information you learn in this chapter to complete the project.

Assessments

- Prior knowledge quiz
- Chapter review questions
- End-of-chapter test
- Depth study: Project

Videos

- Science skills in a minute: Risk assessments (15.5); Organising data into charts (15.8)
- Video activities: Forms of energy (15.2); Rube Goldberg machine (15.4); Heat transport (15.6); Energy transformation (15.7); Geothermal energy (15.10)

Science skills resources

- Science skills in practice: Risk assessments (15.5); Energy transfers and transformations (15.8)
- Extra science investigations: Transferring and transforming energy (15.7); Transforming gravitational energy (15.7)

Interactive resources

- Simulations: Kinetic and potential energy (15.2); Energy transfers (15.4)
- Drag and drop: Types of kinetic energy (15.1); Renewable or non-renewable? (15.7)
- Match: Types of potential energy (15.2)
- Label: Energy transfer diagrams (15.4)

15.1 Kinetic energy

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe different types of kinetic energy
- ✓ classify examples of energy as kinetic energy
- ✓ explain why examples of energy are classified as kinetic energy.



Interactive resource
Drag and drop:
Types of
kinetic energy

GET THINKING

We often take concepts such as energy for granted, especially as we are unable to see energy directly. We know energy exists from how we experience it or by identifying where it comes from. Think about the types of energy you use every day and what would happen if this energy wasn't available.

What is kinetic energy?

energy

the ability to do work, such as moving or cooking, or the potential to do work, such as the chemical potential energy stored in food

work

energy that is being transferred or transformed

kinetic energy

the energy of an object due to its motion

joule (J)

the metric unit of measurement for energy

calorie (cal)

the imperial (non-metric) unit of measurement for energy

In science, **energy** is defined as the ability to do **work**. The type of energy is described by where it comes from or how we experience the energy. One type of energy is known as **kinetic energy**. It is defined as the energy of movement, or the energy possessed by objects or particles that are in motion (Figure 15.1.1).

Energy is measured using the metric unit called the **joule (J)**. The joule is named after scientist James Prescott Joule (1818–89), who completed many investigations about energy. The joule is a very small unit, so energy is more commonly measured in kilojoules (kJ), a unit of 1000 joules. You may also be familiar with the imperial unit of **calorie (cal)** that is still often referred to in food energy values.

Types of kinetic energy

There are several types of energy that are examples of kinetic energy. All of these share the common characteristic of movement of an object or particles. Some of these types of energy may be obvious to you, whereas others may not. Some motion we may be able to see, such as a moving truck or car, whereas other motion is not visible. Can you think of forms of energy where we cannot directly sense particles that are in motion?



▲ FIGURE 15.1.1 Skateboarding is an example of kinetic energy in action.

Sound energy

Sound energy is a form of kinetic energy. It is classified as kinetic energy because when sound travels through a medium, such as air or water, it makes the medium's particles vibrate. These vibrations travel as a sound wave. If you place your hand over the speaker of a mobile phone when it is playing music, you can feel the vibrations. Sound energy can even break glass (Figure 15.1.2). We use sound energy to communicate when we talk to one another. Consider what else you know about sound.



▲ FIGURE 15.1.2 Sound energy can break glass.

Observing sound energy

☆ ACTIVITY 1

Materials and equipment

- tuning fork
- Petri dish
- water

Procedure

- 1 Strike the tuning fork on a hard surface and place the tuning fork close to your ear. What can you sense?
- 2 Touch the tuning fork on your earlobe. What do you sense now?
- 3 Touch the prongs of the tuning fork to the surface of a Petri dish of water. What do you observe?

Analysis

Explain why you can see the sound energy in the water.

Heat transfer

Thermal energy is a form of kinetic energy because it relates to particle vibration. The more thermal energy an object has, the more its particles vibrate. The particle theory states that all particles are moving. As a substance is heated, the movement of the particles increases, and the temperature of the substance increases. When the substance cools, the particles slow down, and the substance's temperature will slowly decrease.

When thermal energy is transferred from one object to another, this is referred to as **heat**. Heat is the energy transferred from one object to another because of a difference in temperature. When hot objects are brought close to colder objects, heat is transferred from the hotter object to the cooler object. Why does the ground feel hot when you walk on it with bare feet during summer? This experience is an example of how hot objects transfer heat to colder objects.



▲ FIGURE 15.1.3 Hot sand transfers heat to your (colder) skin.

sound energy

energy transferred as a wave through or by vibrations

thermal energy

energy contained within an object by its vibrating particles, which determines an object's temperature

heat

thermal energy that is being transferred between different places or particles

☆ ACTIVITY 2

Observing thermal energy

Materials and equipment

- metal rod or ruler
- adhesive putty (Blu Tack)
- drinking cup
- hot water

Procedure

- 1 Attach a piece of adhesive putty about halfway along the metal rod. Feel the temperature of the metal.
- 2 Place one end of the metal rod into a cup of hot, but not boiling, water. Wait a few minutes and describe what happens to the rod and the adhesive putty.
- 3 Carefully take the metal rod out of the water. Describe its temperature now compared to earlier.

Analysis

Explain why there was a change in temperature.

! Safety

Hot water can scald you. Take care when working with hot water in the lab.

In Activity 2, at first the metal rod probably felt cooler than your hand. When you placed the metal into the hot water, the water transferred some of its thermal energy to the rod. The adhesive putty gained energy from the metal rod, heated up and may have fallen off the metal rod.

Electrical energy

electrical energy
energy carried by charged particles in electric circuits

One of the most common forms of kinetic energy that we all use every day is **electrical energy**. We usually refer to this as electricity. Electrical energy is a form of kinetic energy because it involves the movement of charged particles. Appliances and devices are plugged into power points to receive electricity to make them work. Electrical energy is transferred by charged particles moving through a conducting circuit.

15.1 LEARNING CHECK

- 1 **List** three examples of objects that possess kinetic energy.
- 2 **a Describe** two types of energy that are classified as kinetic energy.
b Explain why your examples are types of kinetic energy.
- 3 A string telephone can be made with two cups and a piece of string as shown in the figure. **Explain**, in terms of kinetic energy, the process by which sound leaving the person's mouth can be transferred to the other person's ear.
- 4 **Construct** a table that summarises the type of kinetic energy and the source of the movement observed. Use the headings 'Type of kinetic energy' and 'Source of movement'.



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15.2 Potential energy

15.2

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe different types of potential energy
- ✓ classify examples of energy as potential energy
- ✓ explain why examples of energy are classified as potential energy.

GET THINKING

Imagine standing on a ledge above a river with a bungee cord attached to your ankles. You are about to step off the ledge and plummet down. What changes in energy type will occur as you fall and as the bungee cord stretches? What about the changes in energy type that occur after you have stopped moving down and start moving up again?



Video activity
Forms of energy

Interactive resources
Simulation: Kinetic and potential energy

Match: Types of potential energy

What is potential energy?

Potential energy is energy stored within an object or material. Energy that is stored in some way has the potential to make something happen or to do work. Much of the energy around us is a type of potential energy.

potential energy
energy that is stored, ready to be transformed to another type of energy

Types of potential energy

There are several types of energy that are examples of potential energy. All involve stored energy that has the potential to do work. Can you think of types of energy that are stored?

Gravitational potential energy

The news sometimes describes objects falling as a result of some event. In mountainous regions, avalanches occur regularly because material, such as ice, has **gravitational potential energy**. Gravitational potential energy (usually just referred to as ‘gravitational energy’) is the potential energy associated with how high an object is above some reference point. As it is lifted higher above its starting height, its gravitational energy increases. As the object falls, gravitational energy is converted to kinetic energy. When it hits the ground, it has no remaining gravitational energy. For example, skydivers convert gravitational energy into kinetic energy as they fall towards the ground. When unstable topsoil on a mountain or hill becomes saturated with water, the extra weight can cause it to slide over the ground or rocks beneath in a landslide or mudslide (Figure 15.2.1). The topsoil had gravitational potential energy, which was converted to kinetic energy as it slid.

gravitational potential energy
energy associated with the position of an object above a reference height

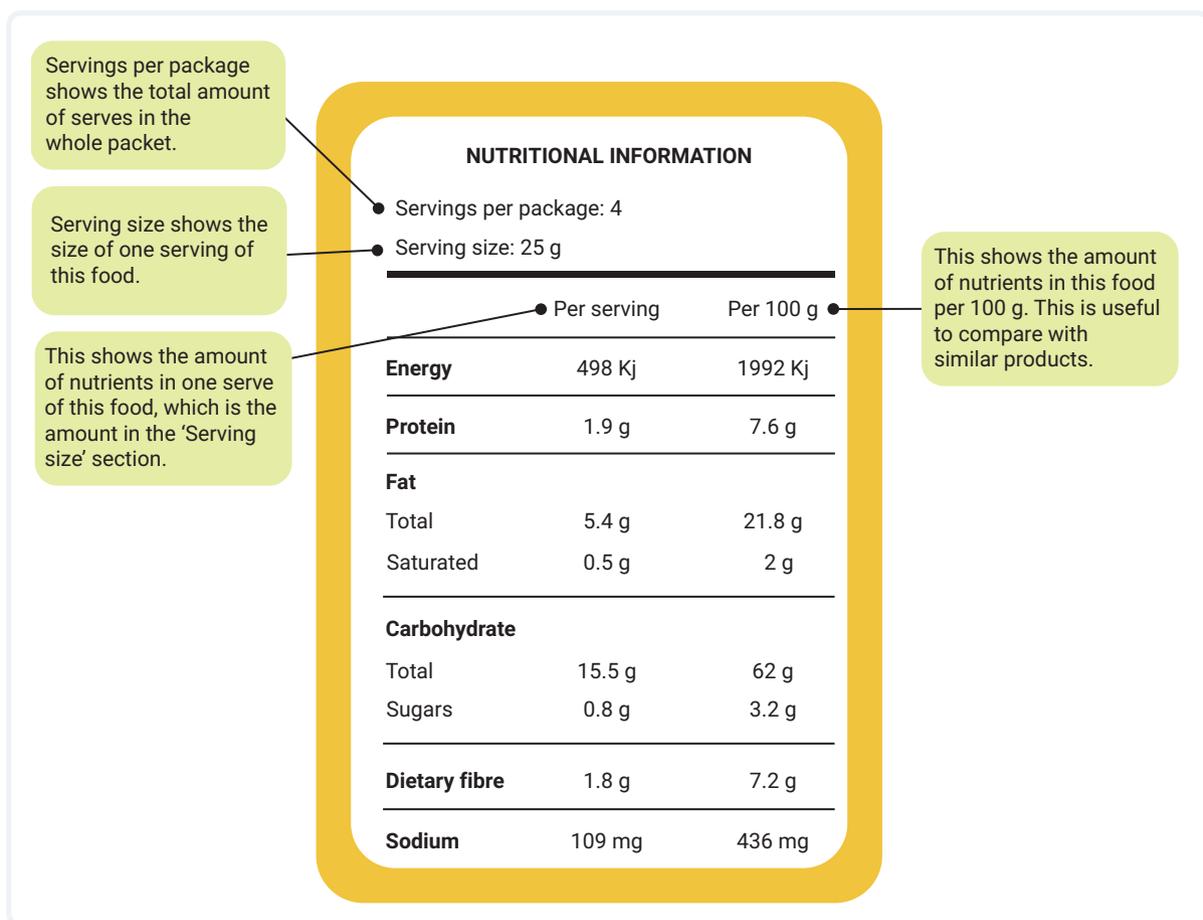


▲ **FIGURE 15.2.1** A landslide caused by heavy rain and storms completely blocked a local road in the Bilgola Plateau in Sydney, March 2022.

Chemical potential energy

Where do you get the energy to do all the things you do every day? This energy comes from food. The food we eat contains chemicals that our body converts into energy through chemical reactions. These chemicals contain **chemical potential energy** (sometimes referred to as ‘chemical energy’). The energy supplied enables your body to carry out its natural processes, such as thinking, breathing and moving the blood around your body, as well as doing physical work, such as walking and talking.

chemical potential energy
energy stored in the chemical bonds of a substance and released when the substance reacts



▲ FIGURE 15.2.2 A typical food label used in Australia

On the labels of most packaged foods is a table that lists the main groups of chemicals contained in the food, and how much chemical energy is released from consuming a measured quantity of that food (Figure 15.2.2).

Fuels such as natural gas, wood, coal and petrol have chemical potential energy. This stored energy is converted to thermal energy and sound energy when we burn the fuel. The chemicals contained in a battery also have chemical energy. When a battery is connected in an electrical circuit, chemical energy can be transformed into light energy, thermal energy, sound energy and other types of energy.

☆ ACTIVITY

Examining food labels

Procedure

- 1 Draw a table with three columns: 'Food group', 'Energy value' and 'Quantity consumed'.
- 2 Include energy value information from the labels of food and drinks that you consume throughout the day. Make a note of how much of each type you consume.

Analysis

- 1 Which groups of foods have the highest energy values?
- 2 Which groups of foods have the lowest energy values? You may be surprised by the chemical energy contained in fast foods.

Elastic potential energy

When you squash or stretch a spring, the energy you use to squash or stretch it is stored in the spring as **elastic potential energy** (usually referred to ‘elastic energy’). This energy does work when the spring is released. When you stretch a material, such as an elastic band, the energy you used to stretch it is stored in the elastic band. It is possible to release this energy later. A bungee cord is made of a spring-like elastic material. The cord stretches and stores the energy as elastic potential energy (Figure 15.2.3).

Elastic energy is used in wind-up toys, in springs and, as we have seen, bungee cords. It is also elastic energy that enables you to bounce a basketball or a tennis ball, and is the energy stored in an archer’s stretched bowstring (Figure 15.2.4).



David Madison/Getty Images

▲ **FIGURE 15.2.3** The bungee cord stores energy as elastic potential energy. It has the potential to release the energy and pull the person at the end of the cord back upwards.

elastic potential energy
energy stored in a spring or elastic material



iStock.com/Dangubic

▲ **FIGURE 15.2.4** Potential energy is stored energy that has the potential for later use. The archer pulls back on the bowstring and the elastic energy it holds is released to give the arrow the kinetic energy to move.

15.2 LEARNING CHECK

- 1 **List** three objects that possess potential energy.
- 2 **Describe** two types of energy that are classified as potential energy.
- 3 Gravitational potential energy plays an important role in many professional sporting events. **Explain** why the landing area of a pole vault has a lot more cushioning than for a high jump.
- 4 **Explain** why a netball that has been thrown into the air possesses both kinetic and potential energy.

15.3 Open and closed systems

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe open and closed systems, including different examples
- ✓ compare and contrast open and closed systems.

GET THINKING

Matter and energy are transferred in situations around us all the time. Looking around you, can you think of some situations in which these transfers happen in a range of sizes from very small to very large? In science, we can describe a group of places or objects from which and to which energy transfers occur as a 'system'.

Systems

system

a collection of objects or items within a boundary

transfer

the movement of something from one place to another

In science we often imagine a boundary around a collection of objects or items and describe that as a **system**. These items can be of any size – as small as a particle or as large as a planet. You can describe a library or the inside of a refrigerator as a system.

It is helpful to think about the **transfer** of energy or matter into and/or out of that system. We classify systems as open or closed. To classify a system, we have to study the system and its surroundings to understand exactly how matter and energy is transferred.

Closed systems

closed system

a system that does not allow transfer of matter in or out of the system

A **closed system** is one where no matter is transferred in or out. However, energy can be transferred into and out of closed systems. A refrigerator with the door kept closed is an example of a closed system:

- some energy is transferred in and out – although it's well insulated, heat will still transfer in and out
- no matter is transferred – with the door closed, no matter can enter or leave the fridge.

A thermos containing hot soup with its lid tightly closed is another example of a closed system.



▲ FIGURE 15.3.1 A closed refrigerator and a thermos are examples of closed systems.

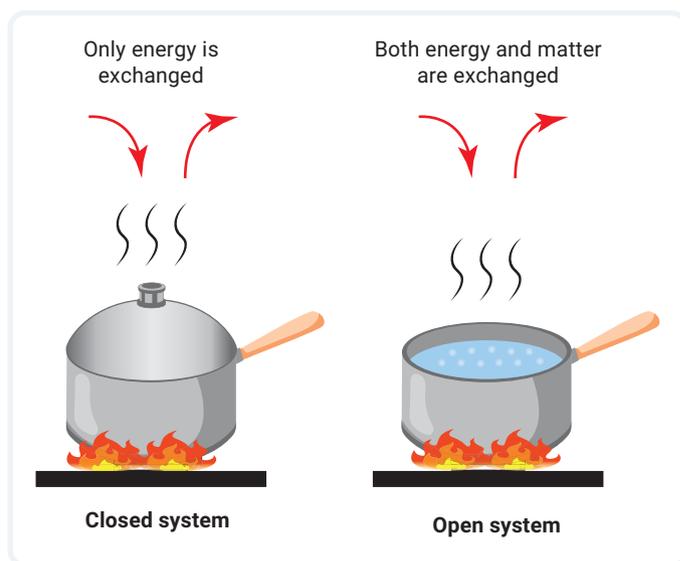
Open systems

Both energy and matter can be transferred into and out of an **open system**. Most systems are classified as open systems.

A library is an open system, even when it is closed at night, because:

- energy is transferred – heat, light energy and sound energy can move in or out through walls and windows
- matter is transferred – books are returned in out-of-hours chutes.

A good way to compare an open system and a closed system is to think about a saucepan on a stove (Figure 15.3.2). When the lid is on, the system is closed and only energy is transferred. When the lid is off, the system is open and both energy and matter are transferred.



▲ **FIGURE 15.3.2** A saucepan on a flame can be either a closed or an open system.

open system

a system that allows the transfer of matter in and out of the system

15.3 LEARNING CHECK

- 1 **List** three open and three closed systems in your kitchen that haven't been mentioned in this module.
- 2 **Explain** how a closed system is different from an open system.
- 3 **Describe** a change you could make to one of the closed systems from your list in question 1 that would make it an open system.
- 4 **Compare** the features of the closed systems from your question 1 list with those of the open systems. What is the common difference between them?
- 5 Is Earth a closed system? **Justify** your answer.



15.4 Energy transfer

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe how energy is transferred through energy systems
- ✓ use flow diagrams to model energy transfer.



Video activity
Rube Goldberg machine

Interactive resources

Simulation: Energy transfers

Label: Energy transfer diagrams

GET THINKING

Energy is more useful in our lives when we can transfer energy between objects; for example, the transfer of heat that takes place when cooking. As you complete this module, think about other examples of energy transfers that take place within your home or at school.

Everyday energy transfers

When cooking, a source of energy such as natural gas is used to produce heat, which is transferred to the cooking utensil and the food that is being cooked. But what do we mean by **energy transfer**? Energy occurring in one place can be passed on as the same type of energy to another place. If you kick a football and it moves, some of your foot's kinetic energy is transferred to the ball to make it move. When a kettle of water is boiled, heat is transferred from the heating element to the water. These are examples of everyday energy transfers (Figure 15.4.1).

energy transfer

the movement of a single type of energy from one place to another or from one body to another



▲ FIGURE 15.4.1 Energy can be transferred from one place to another.

You should now also be familiar with types of kinetic and potential energy. In this module, we will explore how these types of energy are transferred.

law of conservation of energy

a law of physics that states that energy cannot be created or destroyed

isolated system

a system in which no energy or matter is exchanged with its surroundings

Law of conservation of energy

Before going into energy transfer in more detail, let's briefly look at the **law of conservation of energy**. This law states that, in any **isolated system**, energy cannot be created or destroyed. This indicates that the total amount of energy within any isolated energy system must remain constant.

Examples of transferring energy

Energy, in its various forms, may be transferred from one object or location to another. The scientific way of describing energy being transferred is *doing work*. Heat is often the form that energy takes when being transferred. Table 15.4.1 provides some examples of what is needed to transfer energy and some simple examples.

▼ TABLE 15.4.1 Examples of energy transfer

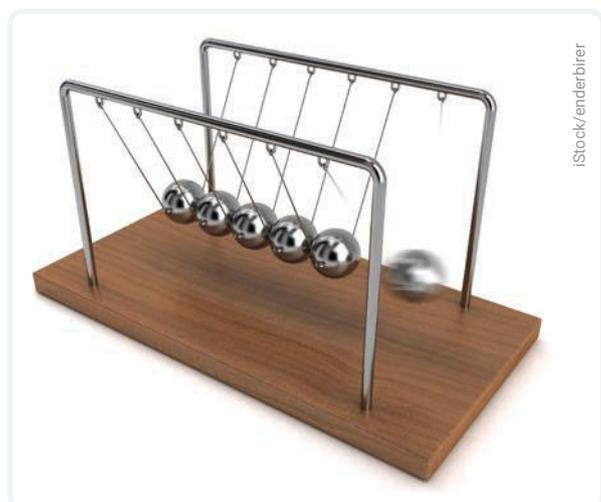
Energy transfer	Examples
Mechanical, involving a force	<ul style="list-style-type: none"> On a pool table, a moving white ball collides with and transfers some of its kinetic energy to a stationary red ball, forcing it to move.
Electrically, involving an electric current	<ul style="list-style-type: none"> An electric current from a power point is transferred through a charger to the battery of a computer or tablet.
Using sound waves	<ul style="list-style-type: none"> Sound energy is transferred from a guitar to your ear as you hear it being played.
Heating	<ul style="list-style-type: none"> A kettle of water is boiled by a heating element. Heat is transferred to your foot through contact with hot sand.

Transferring kinetic energy

When objects collide, there is a transfer of energy from one object to another. In the example of a footballer kicking a football, some of the kinetic energy in their foot is transferred to the football as their foot contacts the ball. Many sports rely on the transfer of kinetic energy from one object to another. When an object such as a bat strikes a ball, there is a transfer of kinetic energy from one object to another: from the bat to the ball (Figure 15.4.2).



▲ FIGURE 15.4.2 A cricketer transferring kinetic energy from bat to ball



iStock/enderbirer

▲ FIGURE 15.4.3 Newton's cradle – an example of transferring kinetic energy

Can you think of some other sport examples in which kinetic energy is transferred? Other common examples of transferring kinetic energy include accidents, such as when cars collide or when you accidentally knock over an object.

In a Newton's cradle, shown in Figure 15.4.3, the kinetic energy of the end sphere is transferred to the sphere it hits, then continues to be transferred between the stationary spheres until it reaches the sphere at the opposite end, causing it to move.

Hearing a sound is another example of transferring energy as kinetic energy. We are able to hear music or people talking because sound energy has transferred from the source of the sound to our ears (Figure 15.4.4).



MIA Studio/Shutterstock.com

▲ FIGURE 15.4.4 Sound energy is transferred when we (a) hear music being played and (b) hear people talking.



Klaus Vedfelt/DigitalVision/Getty Images



iStock/piranka

▲ FIGURE 15.4.5 Transferring electrical energy to recharge an electric vehicle

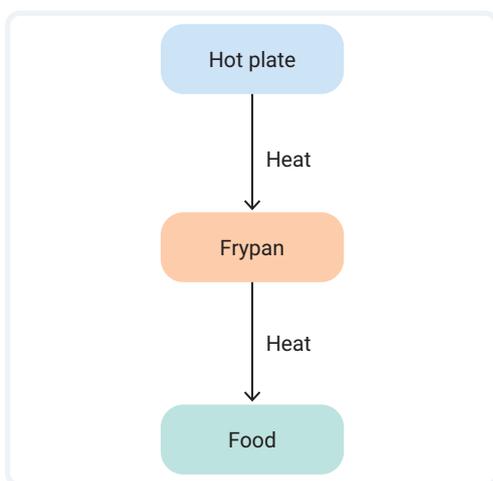
Transferring electrical energy

Electrical energy is another type of energy that is often involved in energy transfers. The transfer takes place by moving charges in electric circuits. All your electrical devices feature a transfer of electrical energy from a power source – which may be a power point or battery – through wires. Distributing electricity from a power station to where it is used – for example, to our houses – requires electrical energy to be transferred. Electric vehicles rely on the transfer of electrical energy to recharge their batteries (Figure 15.4.5).

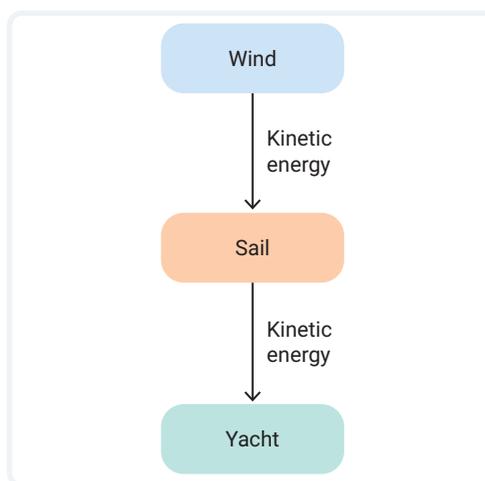
Modelling energy transfer with diagrams

Scientists often use diagrams to represent the flow of something. When discussing energy, the flow of energy can be represented using a flow chart. In a flow chart, the arrow shows the direction of the energy transfer from the source of the energy to the receiver. We will use the example of cooking food (Figure 15.4.6). An arrow shows the flow of the input energy, a box contains the receiver of the energy, and an arrow is pointing to the energy output.

Consider another example of wind moving a yacht. The kinetic energy of the wind is captured by the sail to transfer kinetic energy to the yacht (Figure 15.4.7).



▲ FIGURE 15.4.6 Example of a simple energy transfer diagram



▲ FIGURE 15.4.7 The transfer of kinetic energy from the wind to the sail of a yacht

15.4 LEARNING CHECK

- 1 **Describe** energy transfer by using an example.
- 2 **Identify** the energy transferred from a lit gas hot plate to a saucepan of water.
- 3 **State** the law of conservation of energy.
- 4 **List** three common devices in your household that require a transfer of electrical energy.
- 5 **Construct** an energy transfer diagram for a hockey player hitting a ball.
- 6 **List** three common devices in your household that transfer energy mechanically using a force.
- 7 **Explain** why energy is more useful to us when it is transferred between objects.
- 8 **Describe** how a transfer of kinetic energy can be:
 - a helpful.
 - b harmful.

DATA
SCIENCE



Learn more about
scientific models in
Module 2.9.

15.4



Conducting risk assessments

SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ conducting a risk assessment before an investigation
- ▶ measuring heat transfer.

Safety is a very important part of planning and conducting investigations. There are many potential hazards in the science laboratory but conducting a thorough safety check will help keep you safe. This is called a risk assessment. Before you start your investigation, ask yourself these three questions:

- 1 Is there anything you will be doing or using in the investigation that could cause harm? For example, Bunsen burner, hot liquids or objects, hazardous chemicals, sharp objects
- 2 What are the hazards? For example, burn, eye injury, cut
- 3 What could you do to reduce the risk of harm? For example, use tongs or thermally insulated gloves, wear safety goggles and a lab coat.

Make sure you do this before every investigation. And always remember to record your risk assessment.



Video

Science skills in a minute: Risk assessments

Science skills resource

Science skills in a practice: Risk assessments

MEASURING HEAT TRANSFER

AIM

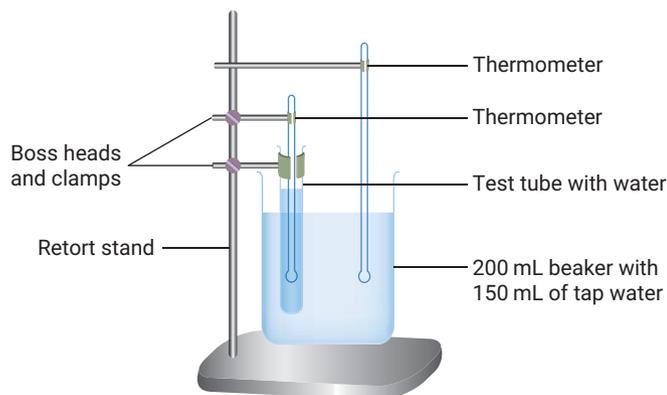
To measure heat transfer from hot objects to cold objects

MATERIALS AND EQUIPMENT

- 200 mL beaker
- large test tube
- 2 thermometers or temperature probes
- retort stand and clamps
- ice water – approximately 0°C
- tap water – approximately 20°C
- hot water – approximately 40°C

PROCEDURE

- 1 Conduct a risk assessment for this investigation. Use the three questions in the 'Science skill in focus' section to help you. What safety equipment do you need to add to your materials and equipment list?
- 2 Set up the experiment as shown in Figure 15.5.1.
- 3 Pour 150 mL of tap water into the beaker.
- 4 Put 50 mL of ice water into the test tube.
- 5 Put a thermometer or temperature probe in both the beaker and the test tube. Record the temperatures in the first results table.
- 6 Suspend the test tube in the beaker of tap water.
- 7 Measure and record the temperature readings in the data table every 2 minutes for at least 10 minutes. Check that you have only recorded numbers, not units in your results table.
- 8 Repeat the experiment using hot water in the test tube at step 4 in place of the ice water in the test tube.
- 9 Record the data for the second test in the second results table.



▲ FIGURE 15.5.1 The experimental set-up

RESULTS

Record your data in tables using column headings like in the tables below.

Time (minutes)	Temperature in 200 mL beaker (°C)	Temperature in test tube with ice (°C)

Time (minutes)	Temperature in 200 mL beaker (°C)	Temperature in test tube with hot water (°C)

ANALYSIS

- On the same set of axes, plot a graph showing temperature versus time for:
 - tap water and ice water
 - tap water and hot water.
- What happened to the temperature in the test tube containing ice water over the time period?
 - What happened to the temperature in the test tube containing hot water over the time period?
 - How do you explain each of these observations?

CONCLUSION

Write a conclusion for the experiment. Make sure you relate it to the aim of the experiment.

15.6 Conduction, convection and radiation

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe the three ways in which heat is transferred, including examples
- ✓ compare and contrast conduction, convection and radiation.



Video activity
Heat transport

Interactive resource
Drag and drop:
Conduction,
convection
and radiation

GET THINKING

On a cold morning, a hot cup of tea warms your hands. And sitting by a fire pit on a cold night will warm your legs. Both activities leave you feeling toasty and warm, but how is the heat transferred from the cup and the fire to you? Write down your ideas and discuss with a partner. At the end of this module, go back and check your thinking.

In this chapter, you have learned that heat is thermal energy that is transferred from one place to another. Heat can be transferred in three ways: conduction, convection and radiation.

Conduction

conduction

the transfer of heat through substances by direct contact, usually solid objects

conductor

an object that allows heat to transfer easily

insulator

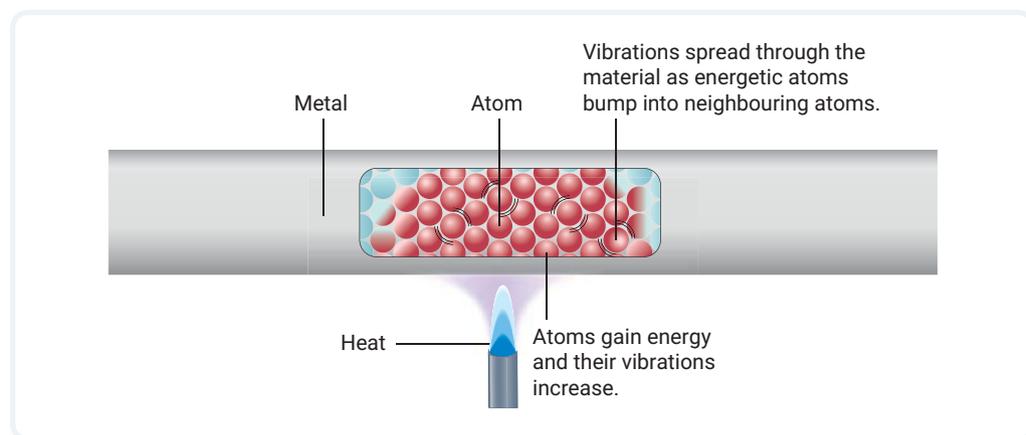
an object that does not transfer heat well

Conduction is a method of heat transfer that mostly occurs in solid objects. The physical and chemical characteristics of a material determine how well it can conduct heat. For example, metals are good **conductors** of heat. But wood, wool, polystyrene and fibreglass are poor conductors of heat. This makes these materials good **insulators**.

Conduction occurs when the particles that make up a solid object bump into each other and transfer heat. The particles of all objects are constantly undergoing tiny vibrations. The amount of vibration depends on the temperature of the object. The hotter an object, the more thermal energy it has and the more its particles will vibrate.

When the particles in one part of an object have more thermal energy, and vibrate more, they bump into particles near them more vigorously (Figure 15.6.1). In turn, these neighbouring particles vibrate more and bump into their neighbours, and so on. Heat, in the form of this collection of vibrations, is passed through the object.

If you have ever left a metal spoon in a pot of hot soup, you might notice that the handle of the spoon becomes warm. This is an example of conduction.

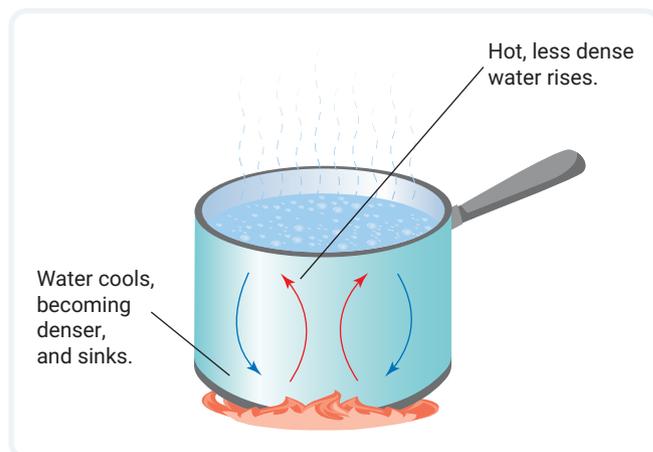


▲ FIGURE 15.6.1 The process of heat transfer by conduction

Convection

Convection is the transfer of heat through liquids and gases, which are also called **fluids**. This process occurs because when the temperature of a substance changes, its volume will also change. Generally, when something becomes hotter it expands, and when it becomes cooler it contracts.

If you heat a saucepan of water over a flame, the water at the bottom expands. Because its volume has increased, the water at the bottom is now less dense than the water above it. This less dense, hotter water rises upwards from the bottom to float, and the cooler, denser water at the top sinks downwards (Figure 15.6.2). In this example, the thermal energy in the saucepan has been transferred from the bottom to the top by convection.

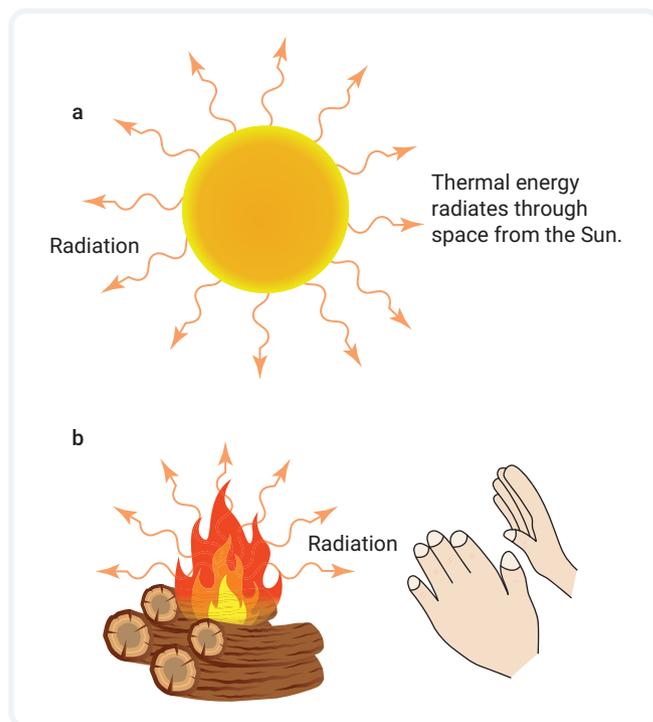


▲ **FIGURE 15.6.2** Water of different temperatures has different densities, and this leads to heat transfer by convection.

Radiation

Hot objects transfer heat away from themselves by **radiation** (Figure 15.6.3). In other words, they radiate thermal energy. This thermal energy is radiated in the form of an invisible wave, similar in nature to a radio wave, microwave or ultraviolet radiation.

The wave that radiates thermal energy is called an infrared wave. When an infrared wave strikes an object, it can cause the object's particles to vibrate, resulting in an increase in temperature.



▲ **FIGURE 15.6.3** (a) Thermal energy radiates from the Sun through the vacuum of space. (b) It also radiates through air from a heat source such as a fire.

15.6 LEARNING CHECK

- 1 Define** conduction, convection and radiation.
- 2 List** two personal experiences you have of each form of heat transfer.
- 3 Explain** why the heat from the Sun can only reach us by radiation.
- 4 Describe**, in terms of heat transfer, how a thermos flask keeps hot liquids hot and cold liquids cold.
- 5 Identify** an item from your kitchen that includes a conductor and an insulator. **Justify** your answer.
- 6 Describe** some ways you can stay cool on a hot, sunny day. **Relate** each example to one of the three forms of heat transfer.

convection

the transfer of heat within fluids

fluid

a substance that can flow; a liquid or gas

radiation

the transfer of heat by waves of infrared radiation

15.7 Energy transformation

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe how energy can be transformed through energy systems
- ✓ use flow diagrams to model energy transformation.



Video activity
Energy transformation

Interactive resource
Drag and drop:
Renewable or non-renewable?

Extra science investigations
Transferring and transforming energy
Transforming gravitational energy

energy transformation
the changing of one type of energy into another type of energy

GET THINKING

We rely on energy transformations to make use of different sources of energy to do work in different situations. For example, electric vehicles would not move unless the chemical potential energy stored in their batteries was transformed into electrical energy, which is then transformed into kinetic energy. As you complete this module, imagine what it would be like if energy transformations were not possible in your daily life.

Transforming energy

Transforming energy means to convert one type of energy into another type of energy. We rely on **energy transformations** in all aspects of our life. One important example of energy transformation you learned about in Chapter 12 is when green plants transform light energy into chemical energy (a type of potential energy) by photosynthesis. Our bodies use the chemical energy stored in the food we eat to keep us alive, by transforming it into other types of energy.

Many devices and appliances transfer and transform energy. In many instances, there will be both energy transfer and energy transformations occurring, especially in complex energy systems. Table 15.7.1 provides some examples of energy transformations.

▼ TABLE 15.7.1 Simple examples of energy transformations

Example	Energy transformation(s) involved
Burning a log 	<ul style="list-style-type: none"> • Chemical energy stored in the wood transforms into heat and light energy.
Turning on a torch 	<ul style="list-style-type: none"> • Chemical energy stored in the battery transforms into electrical energy and then into light energy in the bulb. • When left on, the bulb will get hot, showing that some electrical energy has transformed into heat. • When an electric current flows, some heat is generated by the friction of the charges moving through the wires.
Knocking a glass off a table 	<ul style="list-style-type: none"> • Gravitational potential energy is transformed into kinetic energy as the glass falls. • Some kinetic energy is transformed into sound energy when the glass hits the floor and shatters.

Modelling energy transformation with diagrams

In Module 15.4, you were introduced to flow charts to represent energy transfers. We can use similar diagrams to represent energy transformations. Arrows show the direction of energy flow within the system, and the energy types are shown in the order in which transformations take place.

Let's use the example of turning on a torch to construct a flow chart (Figure 15.7.1).

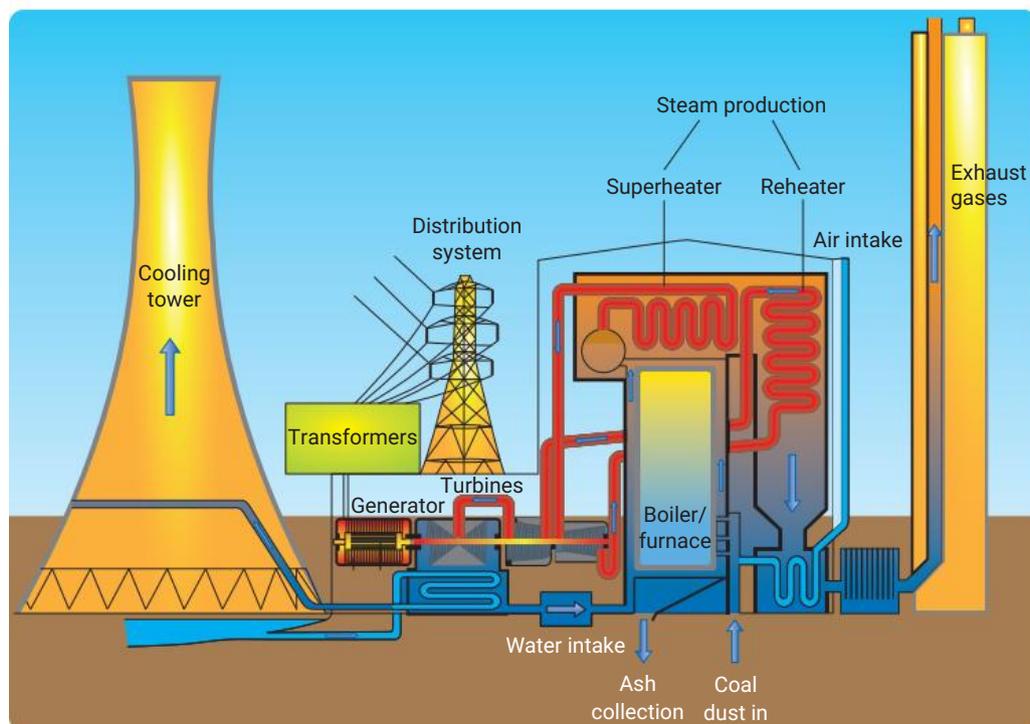
When considering energy transformation diagrams, we are interested in determining the order in which transformations of energy take place. The flow chart is simplified into a chain of connecting energy types (Figure 15.7.2).

Transforming energy into electrical energy

Electrical energy is one of the most common types of energy we depend on every day. We use electricity in our homes, at work or at school, in industry and in many other places. Today's society relies heavily on the electricity generated using various energy sources.

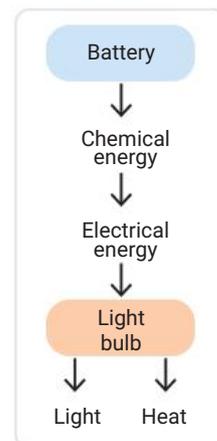
Non-renewable energy sources

Non-renewable energy sources include fossil fuels such as coal, oil and natural gas. Some countries also use nuclear power. Coal has been an important energy source for electricity generation in Australia for many years. Using fossil fuels to produce electrical energy in power stations relies on transforming their chemical potential energy into heat by burning the fuel. The heat is then used to convert water into high-pressure steam. The steam turns a turbine and the kinetic energy of the turbine is transformed into electrical energy (Figure 15.7.3).

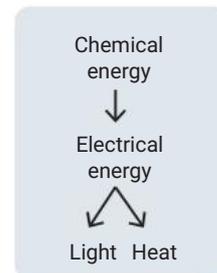


▲ FIGURE 15.7.3 A coal-fired power station

There is now a significant push from the community to shift away from coal and other fossil fuels, and to instead use energy sources that produce fewer **greenhouse gases** and reduce the impact on global warming.



▲ FIGURE 15.7.1 Energy transformations in a torch



▲ FIGURE 15.7.2 A flow chart for chemical energy being transformed into light and heat

non-renewable energy source

a source of energy that is finite in nature; i.e. used at a faster rate than it can be produced

greenhouse gases heat-trapping gases, such as carbon dioxide, that have been linked to global warming

Renewable energy sources

renewable energy source

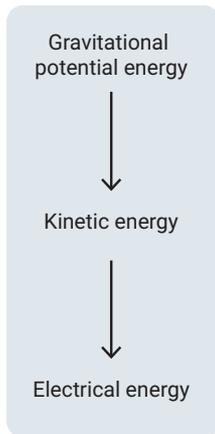
a source of energy that can be produced at a faster rate than it can be used

biofuels

fuels that are made from biological sources that can replace fossil fuels

hydroelectricity

electrical energy produced by transforming gravitational energy of falling water into kinetic energy to drive a turbine



▲ **FIGURE 15.7.4**
A simple energy transformation flow chart for generating hydroelectricity

tidal energy

electricity generated from the ebb and flow of the tides

geothermal energy

heat that is trapped in rocks close to heat sources deep within Earth's crust

wind power

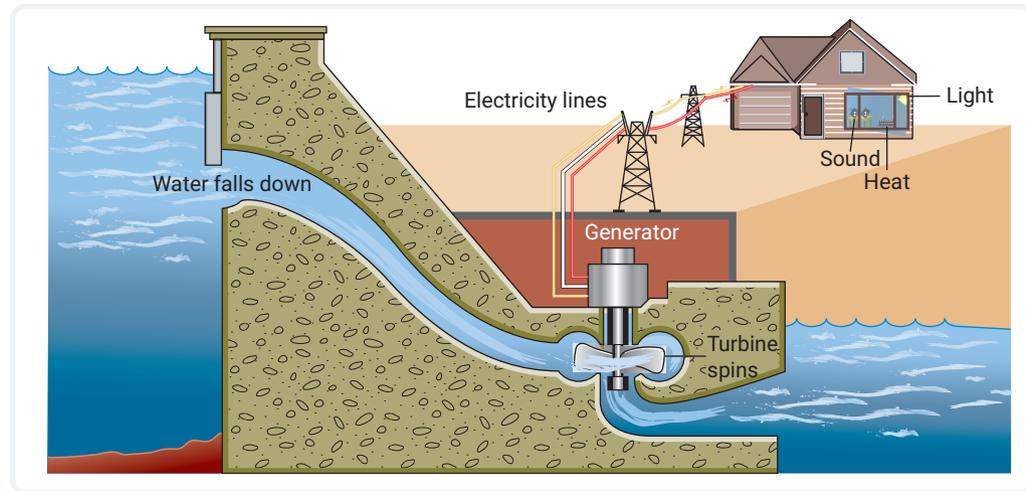
electricity generated by harnessing the kinetic energy of the wind to drive a turbine

solar power

electricity generated directly from sunlight, using solar cells

Renewable energy sources are sources of energy that can be produced at a faster rate than they are used; they can be 'renewed'.

- **Biofuels**, like fossil fuels, are burned to release heat. The advantage of biofuels is that the fuel is made from recycled biological material that would normally be waste material. The energy captured in these materials is used as a fuel rather than ending up being incinerated or breaking down in the environment.
- In the production of **hydroelectricity**, gravitational potential energy is used. Water drops from a height, transforming the gravitational energy into kinetic energy that drives the turbine (Figures 15.7.4 and 15.7.5).



▲ **FIGURE 15.7.5** Transforming gravitational potential energy into electrical energy using a hydroelectric power station

- **Tidal energy** can be used to generate electricity. The kinetic energy of moving water is used to drive a turbine and produce electricity. Some systems use the difference in the heights of the tides to act like the dams in hydroelectric power stations. The water is forced through pipes to rotate turbines.
- **Geothermal energy** is the heat that is trapped in rocks close to heat sources deep within Earth's crust. Geothermal energy is used in New Zealand as a source of electricity. Water, usually pumped into these regions via pipes, is heated and comes back to the surface as steam, under pressure, in separate pipes. The significant kinetic energy of the steam drives a turbine to transform the kinetic energy into electrical energy.
- **Wind power** generators transform the kinetic energy of the wind to drive a turbine to produce electricity.
- **Solar power** relies on converting light energy from the Sun directly into electrical energy in solar cells.

Creating energy flow charts

☆ ACTIVITY

15.7

Procedure

Construct energy flow charts for the energy transformations taking place in each of the following situations.

- 1 Paddling a canoe
- 2 Using a computer or mobile phone to play a computer game
- 3 Swimming
- 4 A plane taking off or landing
- 5 Using a water slide at a theme park
- 6 Surfing

15.7 LEARNING CHECK

- 1 Using a suitable example, **define** energy transformation.
- 2 **Compare** the types of energy involved in a bungee jump from when the person first jumps until they are pulled back up.
- 3 **Explain** the difference between energy transfer and energy transformation, using a suitable example.
- 4 **Construct** a simple energy flow chart to show the energy transformations involved in pedalling a bicycle up a small hill and then going down the other side without pedalling.



Have a nice day Photo/Shutterstock.com

- 5 Using examples, **explain** why heat is produced in many different energy transformations.
- 6 Imagine your house is powered by solar energy and a large battery. **Create** an energy flow chart to show all the energy transformations that would occur if you used a hair dryer at night.



Modelling energy transfers and transformations

SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ using and constructing diagrams to model data
- ▶ using diagrams to communicate information.

In many disciplines of science, diagrams and flow charts are used to provide instruction on how to complete something, such as assembling an apparatus to perform an investigation. Diagrams are also used to describe observations and to model data. In this investigation, you will use energy flow charts to describe your observations and to model the flow of energy in a series of simple activities.

To construct an energy flow chart, you need to:

- identify the initial source of energy and the relevant type of energy the source provides
- make careful observations to identify any energy transfers and transformations taking place
- construct a flow diagram labelling the initial type of energy and using arrows to show the direction of any energy transfers or transformations in the order in which they occur.

In the case of an energy transfer, a box should be drawn around the object receiving and then transferring the energy.

If several energy transformations occur at the same time from one type of energy, the arrows should indicate this.



Video
Science skills in a minute: Organising data into charts

Science skills resource
Science skills in practice: Energy transfers and transformations

MODELLING ENERGY TRANSFERS AND TRANSFORMATIONS WITH FLOW CHARTS

AIM

To model energy transformations and transfers using flow charts

MATERIALS AND EQUIPMENT

- 18 alligator clips
- tennis ball
- buzzer
- 3 × 1.5-volt DC batteries
- 9 connecting wires
- filament light bulb in light-bulb holder
- resistance wire
- 3 switches
- wind-up toy car with an on/off switch

Safety

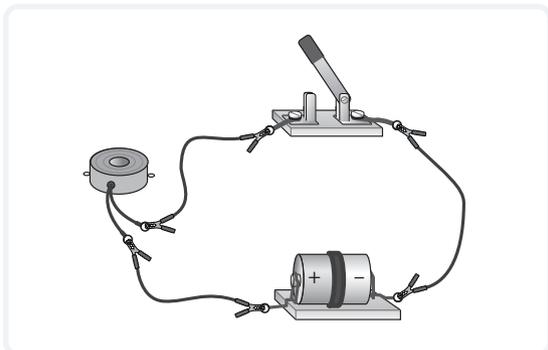
Be careful when handling any equipment that may have sharp edges. Be mindful of any objects that may become hot in this activity. Some may be hot enough to burn your fingers if you touch them for too long.

PROCEDURE

- 1 Construct a suitable table with three columns with headings: 'Object', 'Initial energy type' and 'Observations'.
- 2 Your teacher may have set up five stations to complete this investigation. If so, move around from Station 1 to Station 5.

Station 1 Drop the tennis ball from shoulder height. Record your observations.

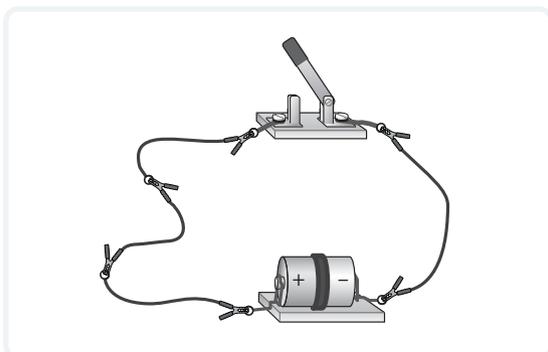
Station 2 Connect the battery to a switch and the buzzer using the connecting wires and alligator clips (Figure 15.8.1). Press the switch. Record your observations.



▲ FIGURE 15.8.1

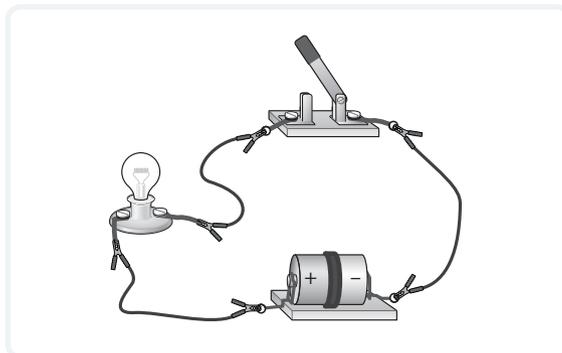
Station 3 Wind up the toy car, making sure the switch is in the 'off' position. Record your observations. Turn the switch of the wind-up toy car to 'on' and place it on the bench or floor. Record your observations.

Station 4 Connect the battery to a switch and the resistance wire (Figure 15.8.2). Feel the temperature of the wire. Press the switch for several seconds and quickly feel the temperature of wire (be careful). Record your observations.



▲ FIGURE 15.8.2

Station 5 Connect the battery to the light bulb and switch (Figure 15.8.3). Feel the temperature of the light bulb. Press the switch for several seconds and feel the temperature of light bulb (be careful). Record your observations.



▲ FIGURE 15.8.3

RESULTS

Construct energy flow charts for each of the five stations. Remember that some of the actions may involve more transfers and/or transformations than others.

ANALYSIS

- Identify which (if any) of the five activity stations are examples of:
 - energy transfer.
 - energy transformation.
- What criteria did you use to distinguish energy transfers from energy transformations in question 1?
- Identify any of the situations that have a combination of energy transfer and energy transformation.

CONCLUSION

Summarise your findings and write a conclusion.

15.9

Traditional fire-making techniques

IN THIS MODULE, YOU WILL:

- ✓ examine how Aboriginal and Torres Strait Islander Peoples transform kinetic energy into heat to make fire.

Traditional tools and methods of fire starting

Prior to the invention of the match in the early 1800s, there were several different methods used for making fire. While in many cultures only one method was used, across Australia, Aboriginal and Torres Strait Islander Peoples knew and used four different methods. These are the hand drill, the fire saw, the fire plough and the percussion methods.

In the first three methods, heat is generated by rubbing two pieces of wood together to produce a glowing ember, which is then used to start a fire. In the percussion method, a piece of flint, resting on tinder (dry material such as grass, that easily catches fire), is struck with glancing blows with a piece of iron pyrite. The striking causes a spark that then lands on and ignites the dry tinder.

The hand drill and fire saw were the most commonly used methods across Australia. The fire plough method was mainly used in north-western Australia, while records indicate use of the percussion method by Aboriginal groups in South Australia and Tasmania.



▲ FIGURE 15.9.1 In the hand drill method, friction produces enough heat to produce a glowing ember. This drill stick and hearth is from south-east Queensland and is made from grass tree and hibiscus.

The hand drill method

The hand drill method (also referred to as the fire drill or drill stick method) was most commonly used across coastal and northern areas of Australia.

Aboriginal and Torres Strait Islander Peoples require the following materials for the hand drill method:

- a drill stick – a long (around 70 cm), thin, straight piece of stick, with one rounded end
- a hearth – a flat piece of wood with an indentation that has a side notch
- tinder – easily combustible material such as small pieces of dried grass or leaves, shaved wood or dried kangaroo dung.

The hearth is placed on the ground and tinder is put under the side notch. The rounded end of drill stick is placed in the indentation in the hearth and twirled vigorously between the hands while applying a downward pressure. The friction between the two pieces of wood produces fine sawdust and heat. The heat causes the sawdust to smoulder, and this ignites the tinder.

The type of timber used for the drill stick and the hearth depended on what was available in Aboriginal and Torres Strait Islander Peoples' Country/Place. Softwood of

the same type was often preferred for both parts. Less energy was required to produce an ember because of the low density and low heat conductivity of softwood. When two different types of wood were used, the drill stick was usually made of the harder wood.

- 1 **Explain** where heat comes from in the hand drill method.
- 2 Draw an energy flow chart to show the energy transformations that happen using the hand drill method.
- 3 **Explain** why less energy is needed to produce an ember when using softwood than when using hardwood.

☆ ACTIVITY 1

The fire saw method

The fire saw method was mainly used by Aboriginal Peoples throughout inland Australia and the north-west coastal area.

Aboriginal Peoples require the following materials for the fire saw method:

- a fire saw – a piece of hardwood with a sharp edge; often, available objects such as a boomerang, spear thrower, coolamon or specially produced wooden knife were used as the fire saw
- a hearth – a softwood shield with a groove, or a split piece of wood held open by wedges (sometimes called a cleft stick)
- tinder – easily combustible material such as small pieces of dried grass or leaves, shaved wood or dried kangaroo dung.



▲ **FIGURE 15.9.2** (a) A cleft stick fire saw hearth (unknown origin) and (b) a Central Desert spear thrower being rubbed in a sawing motion across a shield as the hearth

The hearth is placed on the ground. Pieces of tinder are placed in or around the split or groove. The fire saw is placed across the hearth, resting in a notch. The saw is vigorously pulled back and forth using a sawing motion. As with the hand drill method, sawdust and heat are produced, causing the tinder to catch alight.

☆ ACTIVITY 2

- 1 What type of timber would be the best to use for the hearth? Why?
- 2 **Draw** an energy flow chart for the fire saw method.
- 3 **a Compare** the hand drill and fire saw methods.
b Identify which method you think would be the most energy efficient and **explain** why.
- 4 Figure 15.9.3 shows a demonstration of the fire plough method. Figure 15.9.4 shows a close-up of the fire plough. Using what you have learned, **suggest** materials and a technique for this method.



▲ FIGURE 15.9.3 The fire plough method



▲ FIGURE 15.9.4 A close-up view of a fire plough

- 5 The percussion method involves using a piece of flint and iron pyrite to generate a spark. **Compare** this method to the hand drill and fire saw methods in terms of energy changes.

15.10

Geothermal energy for electricity generation

As you learned in Module 15.7, electricity provided through the power grid is central to our lives. At home, at work, at school and in business and industry, we are reliant on electricity as a means of providing information, communication, transport, comfort, safety, food, goods and services.

The electricity we use is generated by processes that transform a variety of energy sources into electrical energy. Each of these methods has advantages and disadvantages.



Video activity
Geothermal energy

Sources of power generation in Australia

Most power generation in Australia comes from the burning of fossil fuels. In 2021, 47 per cent came from coal power stations, followed by 18 per cent from gas and 4 per cent from other non-renewables. Not surprisingly, burning fossil fuels to generate electricity has many serious impacts on the environment, such as:

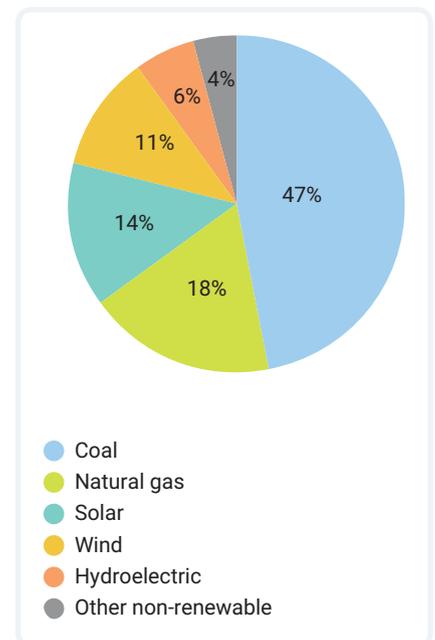
- pollution produced by mining
- pollution from the release of waste products
- pollution in the form of greenhouse gas emissions, which contribute to climate change.

Solar power and wind power produce 14 per cent and 11 per cent of energy in Australia respectively. These are renewable energy sources and neither produce pollution or harmful emissions during generation. However, the production and disposal of resources used in these processes cause pollution.

Hydroelectric power stations produce 6 per cent of Australia's electricity. This process is also free from pollution and greenhouse gases. But it does have environmental impacts, such as the damming of rivers and flooding of valleys to build the dams needed for this type of energy transformation.

Biofuels meet 1 per cent of Australia's electricity demand. This energy source is renewable but it does produce greenhouse gases. It also requires significant land to grow the fuel crop.

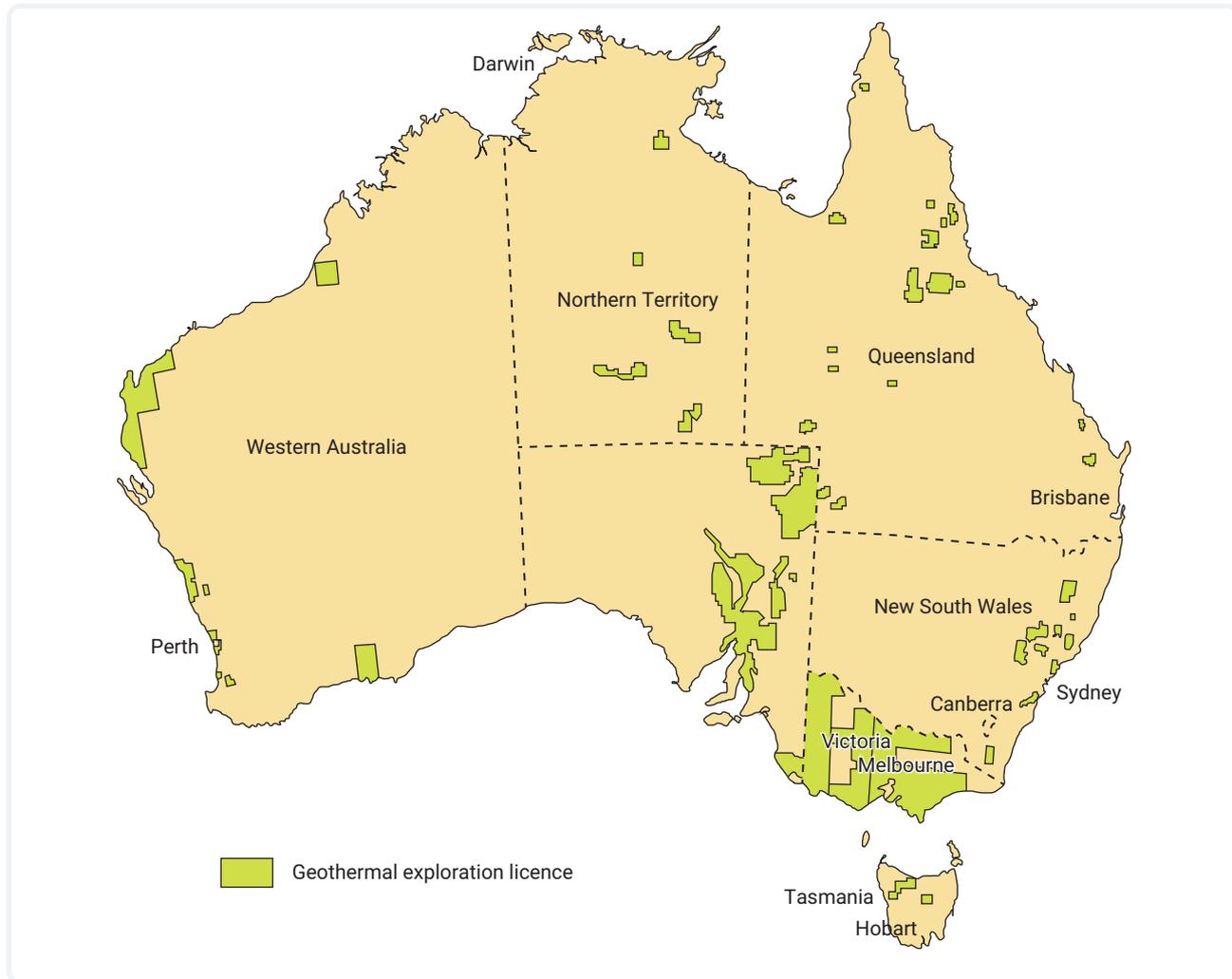
Uranium fission nuclear power stations are used in many places around the world to generate electricity. Australia does not use nuclear power for this purpose.



▲ FIGURE 15.10.1 A pie chart showing Australia's power generation sources

Geothermal energy

Geothermal energy is currently not used in Australia. However, both the Australian Government and private industry believe there is the potential for it to become a major source of electricity generation. There are private organisations exploring the possibility of producing electricity using this method in all states and territories of Australia (Figure 15.10.2).



▲ FIGURE 15.10.2 Regions in Australia where geothermal power exploration is occurring

The United States, Indonesia, the Philippines, Turkey, Iceland and New Zealand are at the top of the list of nations that produce electricity using geothermal energy. In some of these countries, such as Iceland and New Zealand, geothermal energy is meeting 15–20 per cent of their energy needs.

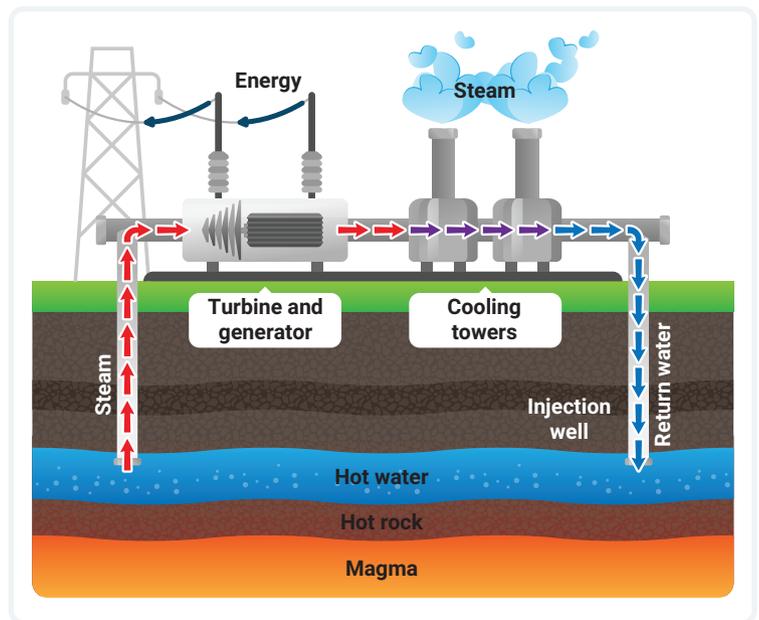
Advantages and disadvantages of geothermal energy

The advantages of geothermal energy include that it:

- produces no greenhouse gas emissions
- is renewable – heat reservoirs will last indefinitely
- produces vast quantities of energy – it is estimated that it could supply around 13 per cent of the world's total energy needs
- is reliable – the resource is always available and not weather-dependent, like wind and solar energy
- requires only a small site for construction and operation.

The disadvantages of geothermal energy include that it:

- can only occur at specific locations – geothermal plants must be built close to the energy source
- may have environmental impacts, because it can release pollutant gas emissions from underground
- has high costs – it is expensive to construct the plants
- is complex – it requires complicated equipment and processes to maintain and operate in the high pressure below the ground.



▲ FIGURE 15.10.3 How a geothermal power plant works

15.10 LEARNING CHECK

- 1 **Define** renewable energy.
- 2 **Create** a table that can compare the main features of each of the main sources of energy generation in Australia. Use the column headings 'Renewable/non-renewable', 'Environmental impacts', and 'Percentage of energy produced'.
- 3 **Explain** why some countries might be better able to use geothermal energy as a power source than others.
- 4 **Describe** how a geothermal power plant produces electricity.
- 5 **Create** a flow chart to represent how geothermal energy transforms into different types of energy at a geothermal power plant.

15 REVIEW

REMEMBERING

- 1 **Define** kinetic energy.
- 2 **Define** potential energy.
- 3 How do scientists define energy?
- 4 **Name** three open and three closed systems.
- 5 **Identify** the following sentences as true or false. If they are false, rewrite them to make them true.
 - a Cold objects transfer heat to hot objects.
 - b An avalanche transforms gravitational potential energy mostly into sound energy.
 - c Boiling water using an electric kettle is an example of an energy transfer.
 - d Transferring energy and transforming energy mean the same thing.

UNDERSTANDING

- 6 Why do we classify chemical energy as a type of potential energy, but we classify heat as a type of kinetic energy?
- 7 **Name** the type of energy stored in a battery.
- 8 **Construct** a flow chart to show the energy transformations in producing electricity using fossil fuels.
- 9 **Name** three objects that store elastic potential energy.

APPLYING

- 10 **Identify** three sources of potential energy stored in your house as:
 - a chemical potential energy.
 - b elastic potential energy.
 - c gravitational potential energy.
- 11 **Explain** why the sources you identified in question 10 are examples of stored energy.
- 12 **Explain** why charging an electric vehicle is an example of an energy transformation. Justify your explanation with a flow chart.
- 13 Fuels are chemicals that can be used to produce electrical energy. **Identify** at least four fuels that are used for this purpose. **Explain** the energy transformations required to use each of these fuels to generate electricity.

- 14 **Name** two different types of energy involved in:

- a playing a sport.
- b recreational activities other than sport.

- 15 **Construct** a flow chart that demonstrates a type of energy you identified in question 14a being transformed into other types of energy.

- 16 **Construct** a flow chart that demonstrates a different type of energy you identified in question 14b being transferred between objects.

- 17 In the action of throwing a netball, a person transfers energy but does not transform energy. Is this statement true or false? **Explain** your answer.

- 18 **Explain** the energy changes that occur in the fire plough method of making a fire.

EVALUATING

- 19 **Explain**, with reference to the concept of conduction, why a saucepan might have a wooden handle.
- 20 A bungee jumper has maximum gravitational potential energy just before they jump. As they fall, gravitational energy transforms into kinetic energy. The jumper slows down as the elastic rope begins to stretch. When they reach the bottom of their jump, the rope pulls them back up.
 - a **Explain** why the bungee jumper slows down as the elastic rope is stretched.
 - b **Explain** why the bungee jumper has maximum gravitational potential energy before jumping.
- 21 **Construct** an energy flow chart to explain the energy transformations of the bungee jumper in question 20.
- 22 **Explain** how convection causes an oven's top shelf to be hotter than its bottom shelf.
- 23 **Explain** why sound energy requires a material for the energy to be transferred.

CREATING

- 24 **Construct** a simple mind or concept map of the key words from the chapter. Make as many links as possible between them.

1 Connect what you've learned

In this chapter, you've learned about types of energy and how they are classified as types of kinetic or potential energy. You have seen examples of energy transfers, where the same type of energy is transferred from one object to another. You have also learned about transforming energy from one type to another. The Rube Goldberg machine shown below contains examples of energy transfers and transformations. Many of the transfers involve transferring kinetic energy from one object to another.

2 Check your thinking

Look carefully at the Rube Goldberg machine. This example involves the use of common items such as balls, rope, pulleys, levers and wooden ramps, as well as some less common and strange items, to make a complex machine. The machine uses a complicated mix of energy transfers and energy transformations to accomplish a task. It is a very complicated way of completing a simple task, but can be a lot of fun!

3 Get into action

Plan your own Rube Goldberg machine individually or as part of a team. The machine must contain at least five steps to complete the simple task of pouring water into a pet's bowl. The machine must include at least two energy transfers and at least three energy transformations. In your planning, you (or your group) may be as creative as you like, but your machine should use common household items. The plan must include an energy flow chart to show the energy transfers and transformations that take place to complete the task.

4 Communicate

Draw a plan for your Rube Goldberg machine. Write a set of instructions, including energy flow charts, to explain how the machine works to complete the task. Construct the machine and film it in operation, explaining the energy transfers and transformations as they occur. Alternatively, you may wish to construct the machine and demonstrate it to other students in your class.

Note: Constructing and filming the Rube Goldberg machine is not part of the assessment.



Jeffrey Coolidge/Getty Images

16

Chemical change

16.1 Physical change (p. 556)

A physical change often leads to a change in appearance, not a change in chemical composition.

16.2 Chemical change (p. 560)

A chemical change results in a new substance being formed.

16.3 Evidence of chemical change (p. 563)

Chemical reactions can be identified by several observable factors.

16.4 WORKING SCIENTIFICALLY: Making observations (p. 566)

Identifying signs of chemical change

16.5 Chemical reactions (p. 569)

Chemical reactions involve rearranging atoms of reactants to form new substances, with energy being released or absorbed.

16.6 Energy change in a reaction (p. 572)

Energy in a chemical reaction is stored in the bonds.

16.7 WORKING SCIENTIFICALLY: Observing to make inferences (p. 575)

Modelling photosynthesis and cellular respiration

16.8 Writing word and chemical equations (p. 577)

Word equations show the reactants and products in a chemical reaction.

16.9 ABORIGINAL AND TORRES STRAIT ISLANDER SCIENCE CONTEXTS: Use of chemical and physical changes (p. 580)

Investigate the ways Aboriginal and Torres Strait Islander Peoples developed pigments and dyes through their understanding of chemical reactions.

16.10 SCIENCE IN CONTEXT: Biodegradable materials (p. 583)

Single-use plastics are being replaced with biodegradable products.



Peter Adams/Getty Images

Tropical rainforests cover approximately 7 per cent of Earth's surface. They are home to more than half of all the plant species on the planet. Via chemical reactions, these rainforests generate around 20 per cent of the oxygen in Earth's atmosphere and are therefore known as the 'lungs of the planet'. Not only do they generate oxygen, they also remove the heat-trapping gas carbon dioxide (CO₂) from the air.

- ▶ Do trees both produce and use oxygen?
- ▶ What chemical processes occur in trees that produce oxygen?
- ▶ How do rainforests reduce pollutants?

▲ FIGURE 16.01 Tropical rainforests are vital to life on Earth.

#16 DIVE INTO SCIENCE!

At the end of this chapter, you can complete Science in Depth Study #16. You can use the information you learn in this chapter to complete the project.

Assessments

- Prior knowledge quiz
- Chapter review questions
- End-of-chapter test
- Depth study: Secondary sources investigation

Videos

- Science skills in a minute: Making observations (16.4)
- Video activities: Changing states of matter (16.1); Chemical reactions in 'food comas' (16.5); Energy change of reactions (16.6); Biodegradable plastic (16.10)

Science skills resources

- Science skills in practice: Observations to make classifications (16.4)
- Extra science investigations: Observing physical change (16.1); What do you know about chemical change? (16.2); Chemical change (16.3)

Interactive resources

- Label: Phase changes (16.1); Evidence of chemical change (16.3)
- Simulation: Phase changes (16.1)
- Drag and drop: Chemical or physical change? (16.3); Signs of a chemical reaction (16.5)
- Match: Equations and reactions (16.2); Word equations (16.8)

16.1 Physical change

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

✓ identify and describe examples of a physical change.



Video activity
Changing states of matter

Interactive resources
Simulation:
Phase changes
Label: Phase changes

Extra science investigation
Observing physical change

physical change

a change in a substance that does not involve the production of a new substance; can usually be reversed

state of matter

one of the forms in which matter can exist: solid, liquid, gas or plasma

plasma

the electrically charged gaseous state of matter that is abundant in stars; often called the fourth state of matter

GET THINKING

What do mowing the lawn and cracking an egg have in common? They are both examples of physical changes, which are occurring all around you in everyday life. Try to think of some other physical changes happening around you.

A change in appearance, not composition

When a substance undergoes a **physical change**, its appearance changes, but the substance is still the same – no new substance is produced and there is no change in the chemical composition of the substance. Physical changes can usually be reversed. You can think of changing a physical property as changing your appearance. You can cut your hair or change your clothes, but you are still the same person as when you started. The change can be reversed by simply growing your hair again or changing back into your former clothes. Let's take a closer look at the most common types of physical changes.

Changes of shape

Changing size or shape is an example of a physical change. If you mould a ball of playdough into a dinosaur shape, it is still playdough, just in a new shape (Figure 16.1.1). You could reverse the process by rolling the dinosaur back into a ball. Changes of shape often occur due to a force being applied; for example, a twist, pull, bend or break.

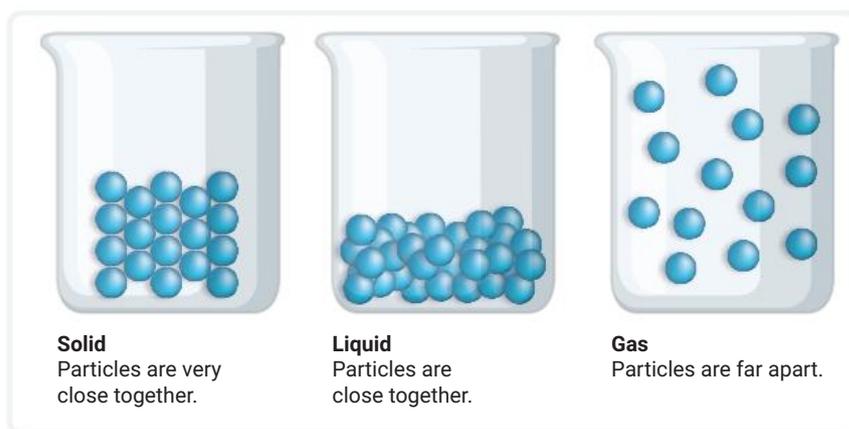
Changes of state and phase change

As described in Module 8.3, a **state of matter** is one of the forms in which matter can exist. There are four natural states of matter: solid, liquid, gas and **plasma**. For example, water has three states: liquid (water), solid (ice) and gas (water vapour). When in different states, water has different physical properties – for example, water in its liquid form can be poured, but water in its frozen form cannot – but it is still the same substance.



▲ FIGURE 16.1.1 Playdough shaped into a dinosaur is still playdough.

States of matter can be represented by 2D particle models, which are similar to the 2D representations of atoms, elements and compounds discussed in Chapter 8. When a substance changes state, the particles do not change; they just move further apart or closer together. Figure 16.1.2 depicts the three states of water.



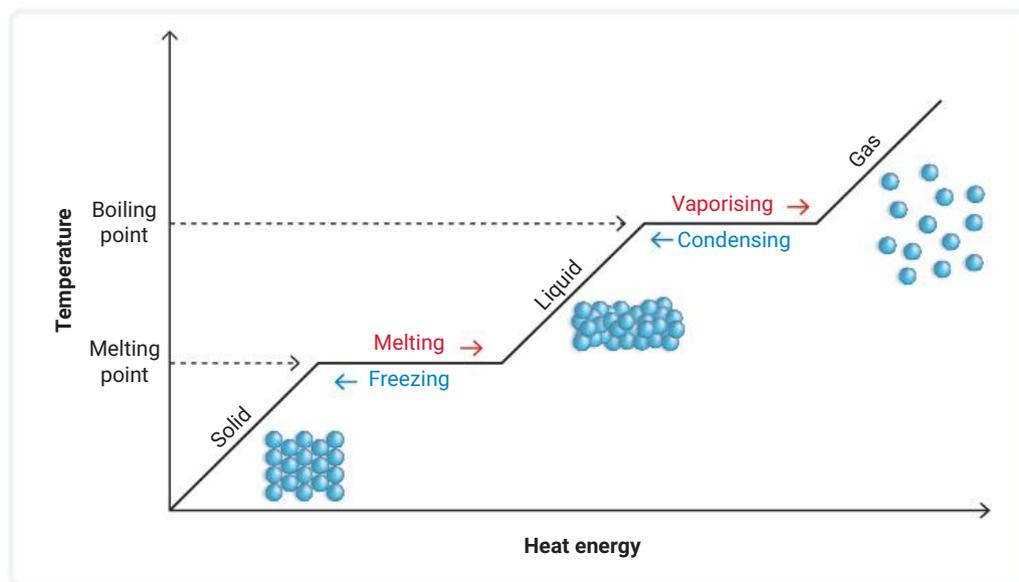
▲ FIGURE 16.1.2 The three states of water

A physical change occurs when a substance changes state in the presence or absence of heat. Put

very simply, **phase change** refers to this change in a state of matter. When liquid water boils to form gaseous water vapour, its properties change. It is now a gas, and we cannot see it, but it is still water. It could also easily be changed back to liquid water by cooling it.

phase change
a change in the state of matter; an example of a physical change

Common phase changes are shown in Table 16.1.1 (on the next page). These can be represented in a chart, called a phase change diagram, which shows the temperature at which each phase change occurs (Figure 16.1.3). The y-axis is temperature. The horizontal section of the data line indicates regions where there is no temperature change; that is, the temperature remains constant as the change occurs. Freezing and melting points are the same temperature. Condensing and vaporising points are also the same.



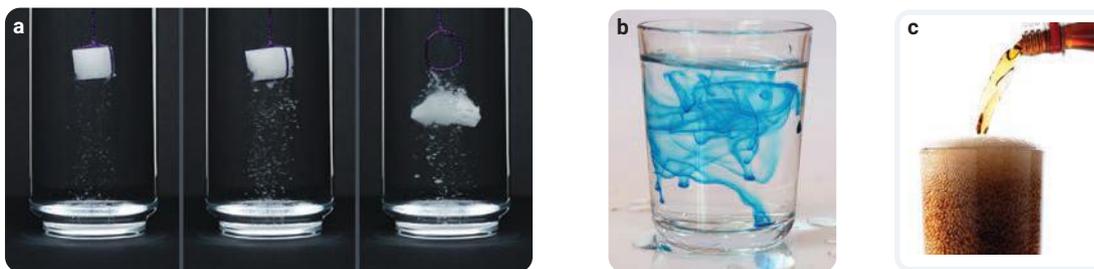
▲ FIGURE 16.1.3 Phase changes involve changes in temperature and heat energy.

▼ TABLE 16.1.1 Types of phase change

Description of phase change	Terminology	Example
Solid to liquid	Melting or liquefying	Ice-cream melting 
Liquid to solid	Freezing or solidifying	Water freezing to ice 
Liquid to gas	Boiling or evaporation (vaporisation)	Water boiling in a kettle 
Gas to liquid	Condensation or liquefaction	Fog on the inside of a window 
Solid to gas	Sublimation (vaporisation)	Dry ice changing into a gas 

Physical change by mixing

A physical change also occurs when two substances are mixed, such as dissolving a solute in a solvent. If solid sugar (solute) is dissolved in water (solvent), we cannot see the sugar but we know it is still there because the resulting solution tastes sweet. If we evaporated the water, we would be left with the original solid sugar. This shows there has been no change to the sugar itself, so it is a physical change. Both liquids and gases can also be dissolved, as shown in Figure 16.1.4.



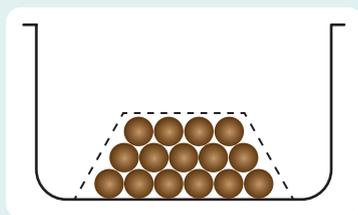
▲ FIGURE 16.1.4 Examples of physical change by mixing: (a) solid sugar dissolving into water; (b) liquid dye mixing with water; (c) gas bubbles in a carbonated drink

In summary, physical changes:

- involve a change of state, shape or form
- are reversible in most cases
- do not create new substances
- do not alter the chemical properties of a substance, but may alter physical properties, including colour, state or density.

16.1 LEARNING CHECK

- 1 List four examples of physical changes you see around you.
- 2 Identify the two components of a solution.
- 3 Recall the opposite process for each of the following phase changes.
 - a Condensing
 - b Freezing
- 4 The figure below shows the particles in a piece of solid chocolate sitting at the bottom of a beaker.



- a Redraw the diagram to show the arrangement of the chocolate particles after heat has been applied.
 - b What evidence could you list to support the idea that a physical change has occurred?
- 5 Use Figure 16.1.3 (p. 557) to answer the following questions.
 - a Condensing and what other change in state occur at the same temperature?
 - b Which physical state exists at the lowest temperature?
 - c Which two processes require the loss of heat from the substance?
 - 6 A student makes the following claim: 'A substance is undergoing physical change because a colour change has occurred, a solid turned into a liquid and a new chemical substance formed.' Assess whether the student's claim is correct.

16.2 Chemical change

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ identify and describe the characteristics of a chemical change
- ✓ explain chemical reactions at a particle level in terms of products and reactants.



Quiz
Chemical change

Interactive resources
Match: Equations and reactions

Extra science investigation
What do you know about chemical change?

chemical change

when the chemical make-up of a substance changes, and a new substance or substances are formed

chemical reaction

a process that occurs when a substance changes to produce a new substance

reactant

a substance used up in a chemical reaction

product

a new substance produced in a chemical reaction

GET THINKING

What do a burning log in the fire, a rusting iron nail and baking bread have in common? They are all examples of chemical reactions. Try to think of some other everyday chemical reactions.

A new substance is formed

You have already learned that the chemical composition of a substance is not altered during a physical change. For example, when liquid water is boiled, it changes state from liquid to gas. Liquid water and gaseous water vapour have some different physical properties, such as their state at room temperature, but they are both still made up of identical H_2O molecules. Water vapour can be easily condensed (that is, reversed) back into liquid water by using distillation equipment in the laboratory.

Unlike physical changes, **chemical changes** are generally not reversible. Chemical change always leads to the production of new/different substances that have different physical and chemical properties from the original substances. A process where a chemical change occurs is called a **chemical reaction**. If a chemical reaction has occurred, the chemical make-up (composition) of the original substance – called the **reactant** – is different from the chemical make-up of the new/different substance produced – called the **product**.

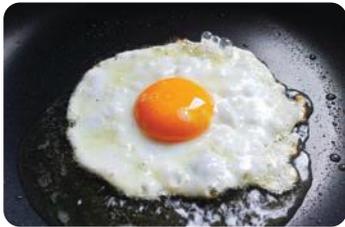
For example, let's examine what happens when a piece of coal burns. When coal burns, it produces new substances such as soot and gases, including carbon dioxide and water vapour. Coal is not the same substance as soot, ash or carbon dioxide gas, so the new substances (the products) have very different physical and chemical properties from the original piece of coal (the reactant). This means the original substance has reacted and undergone a chemical change. The carbon dioxide, and other substances produced, cannot be turned back into coal again. The coal gets 'used up' and so more coal would need to be burned if we wanted to keep a fire going.



▲ FIGURE 16.2.1 Unburnt brown coal

Table 16.2.1 shows other examples of everyday chemical changes.

▼ TABLE 16.2.1 Everyday examples of chemical changes

	Raw egg becomes cooked egg. →	
	Cake mix becomes cake. →	
	Steel becomes rust. →	

In summary, chemical changes:

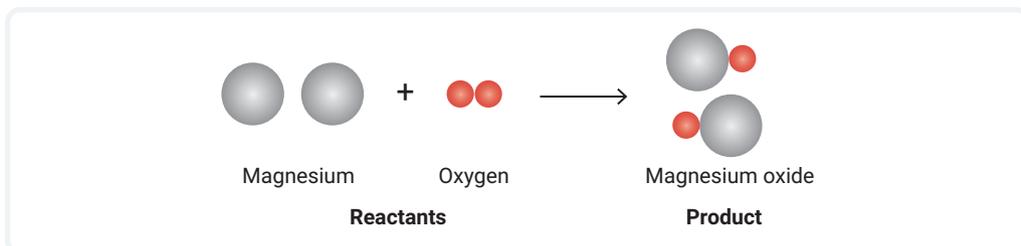
- involve a change in chemical composition
- are often not reversible. If they are reversible, it is by chemical means and is often quite difficult
- produce new/different substances that have new/different physical and chemical properties.

Particle models for chemical changes

As described in Module 16.1, particle models are useful to help understand scientific ideas, such as the differences between solids, liquids and gases. Particle models can also be used to demonstrate chemical changes.

As we learned, when a chemical change occurs, the particles that make up the product are different from those of the reactant. However, it is important to understand what that difference is. Chemical bonds in the reactants are broken, and the atoms rearrange to form new bonds in the products. The atoms do not change types or disappear.

Figure 16.2.2 shows how burning magnesium, Mg, reacts with oxygen, O₂, in the air to produce magnesium oxide, MgO. In this reaction, magnesium and oxygen are the reactants and magnesium oxide is the product. The reaction starts and ends with only two types of atoms: magnesium and oxygen. The reactants consist of the magnesium atoms and oxygen molecules as separate substances. After the reaction, the magnesium and oxygen are bonded to each other. This is true for all chemical reactions: the types of atoms don't change, just the arrangement.



▲ FIGURE 16.2.2 Using the particle model to represent the chemical reaction between magnesium and oxygen

16.2 LEARNING CHECK

- 1 **List** four examples of a chemical change in your everyday life.
- 2 **Draw** particle models to represent the following chemical reactions.
 - a One atom of carbon reacts with a molecule of O₂ (oxygen gas) to produce one molecule of CO₂ (carbon dioxide).
 - b One molecule of ammonia (NH₃) reacts with one molecule of hydrochloric acid (HCl) to produce a molecule of ammonium chloride (NH₄Cl).
- 3 **Compare** chemical changes and physical changes.
- 4 Figure 16.2.2 shows the chemical reaction for burning a piece of magnesium metal.
 - a **Identify** two safety procedures you would need to undertake if you were to do this experiment.
 - b Will the product be different from the reactants in this reaction?
Explain your reasoning.



sciencephotos/Alamy Stock Photo

16.3 Evidence of chemical change

16.3

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe the indicators that are evidence of a chemical change
- ✓ classify change as physical or chemical.

GET THINKING

A burning log fire produces ash and other substances that were not there before. A shiny grey iron nail may turn orange-brown over time as a new substance, called rust, is produced. What other indicators that a chemical change has occurred can you think of?



Interactive resources
Drag and drop: Chemical or physical change?

Label: Evidence of chemical change

Extra science investigation
Chemical change

Indicators of a chemical change

Chemical changes occur at the atomic or molecular level of a substance. Atoms can never be created, and they don't disappear. Rather, the atoms that make up the reactants are rearranged in a different way to form the products, which are new substances that have different chemical properties.

You cannot see atoms or molecules, so how do you know if a chemical change has occurred? When combining two substances, sometimes nothing happens or something happens so slowly that it appears as though nothing is happening. Other times, something will happen immediately to show that a chemical change has occurred (Figure 16.3.1).

In Chapter 14, the pop test was used to identify hydrogen. If you collect hydrogen gas in a cold test tube and place a lit taper over the opening of the test tube, you should hear a 'pop'. This shows the presence of flammable hydrogen gas. It is an example of a chemical change. If you look closely at the inside of the top of the test tube, you may see some colourless drops of liquid. This is water vapour that has condensed on the cold test tube. It shows that when you combine hydrogen gas (H_2) with oxygen gas (O_2), a new substance, water (H_2O), is produced.

Chemical reactions can often be identified by several observable factors. Table 16.3.1 lists some indicators that a chemical change has occurred.



iamlukyeee/Shutterstock.com

▲ **FIGURE 16.3.1** The combustion of fireworks is an example of an immediate chemical change because heat, light and sound are produced when the firework fuse comes into contact with the charcoal-based black powder that acts as a fuel source.

▼ **TABLE 16.3.1** Some indicators that a chemical change has occurred

Reactant atoms rearrange to form:	You will observe:
a product that is a different colour.	a permanent colour change.
a substance that is a gas.	gas (bubbles) given off and/or there may be an odour.
a new solid substance.	an insoluble solid, called a precipitate .
a new substance with different energy.	a temperature change, which can be hotter or cooler, and/or light is given off.

precipitate

a solid substance formed in a solution as a result of a chemical reaction

A colour change

Chemicals often have a characteristic colour. When a new substance is formed during a chemical reaction, it may be a different colour from the reactants. If you leave a half-eaten apple on the table, it will turn brown as it begins to react with oxygen in the air. A shiny grey iron nail may turn orange-brown over time as a new substance, called rust, is produced. These are examples of a colour change during a chemical reaction. However, a colour change does not always indicate that a chemical change has occurred. For example, adding red food colouring to blue creates purple colouring, but this is only a physical change.

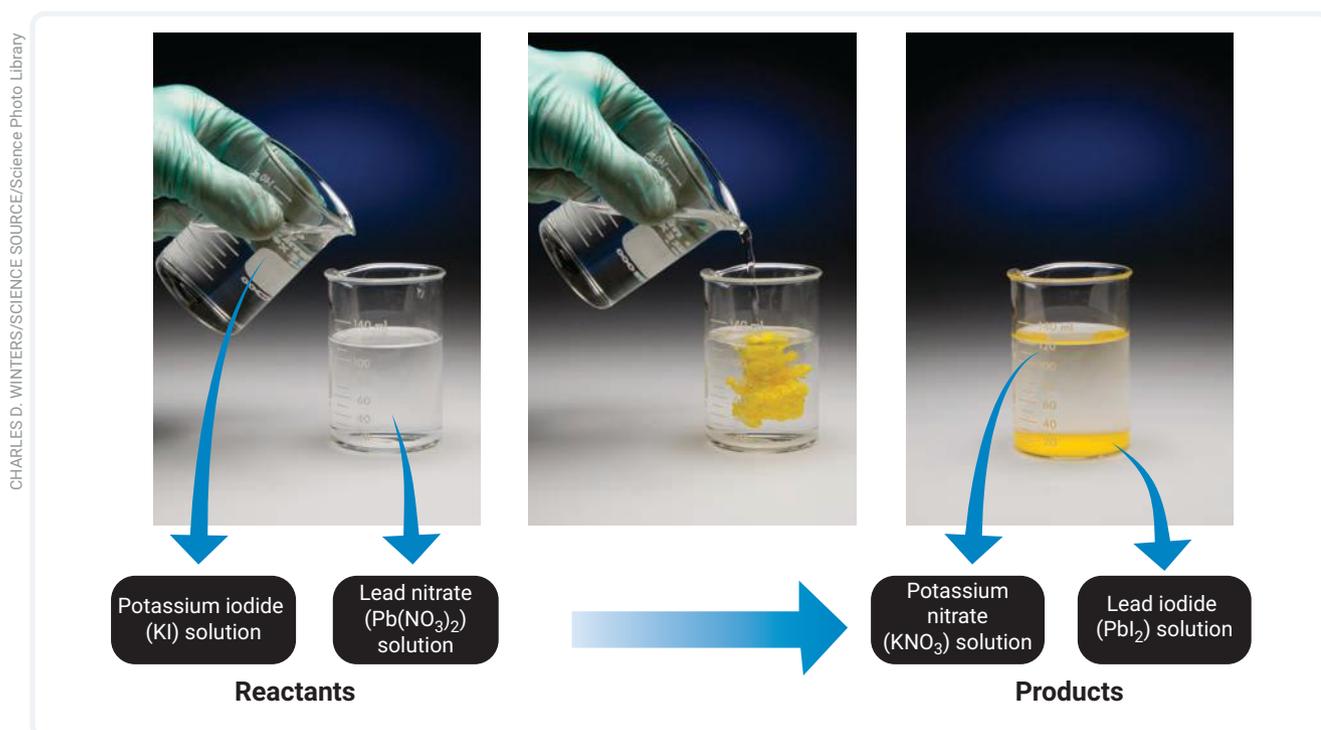
Gas is produced

When reactant atoms rearrange to form a product that is a gas, several things can occur. Sometimes the product has a smell. This is a sign that a chemical change has occurred. A common example of this is the smell rotten food gives off. This smell is quite different from the smell given off when the food was fresh.

Gases can form bubbles in a chemical reaction. An antacid tablet releases bubbles when dropped into a glass of water. When the antacid tablet is in solid form, the two chemicals, commonly citric acid and bicarbonate, cannot react with each other. However, when they are dissolved in water, a chemical reaction between the two occurs and carbon dioxide gas, CO_2 , is given off.

An insoluble solid: precipitate

A precipitate, shown in Figure 16.3.2, is an insoluble substance that can form when two solutions chemically react. The solid substance (the precipitate) makes that liquid appear cloudy. Over time, the solid often settles to the bottom.



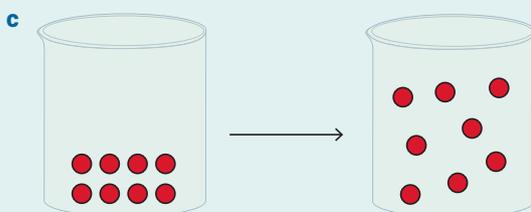
▲ FIGURE 16.3.2 An example of a precipitate forming. In this case, when two solutions chemically react, a yellow precipitate forms.

A temperature change

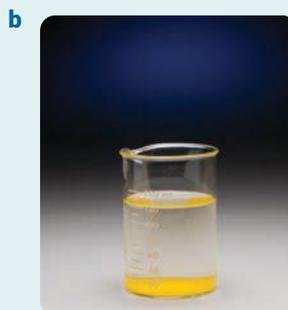
During a chemical reaction, existing bonds are broken and new bonds form. When this occurs, energy is released or absorbed in the form of heat. Heat packs for injuries or keeping warm use chemicals that react together to produce heat.

16.3 LEARNING CHECK

- 1 **List** the indicators that signify a chemical change has occurred.
- 2 **Classify** each of the diagrams below as either a physical or a chemical change.



- 3 Two students each added a level spatula of purple crystals into 100 mL of water in an evaporating basin. The water turned purple and was transparent. Next, they heated the liquid until no more liquid was left. A purple powder (solid) was left in the evaporating basin. One student said that when they added the purple crystals to the water there was a chemical reaction, while the other said there was not.
 - a **Describe** the reasons why the first student thought it was a chemical reaction.
 - b **Describe** the reasons why the second student thought it was not a chemical reaction.
 - c Which student is correct? **Explain** your answer.
- 4 **Analyse** each photo and **identify** the evidence that indicates a chemical change has occurred.



Bleach



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THIS SKILL:

- ▶ identifying observations that indicate a chemical change has occurred.

Observations play a key role in science and in particular in chemistry because they are data that can be analysed and interpreted to reach a conclusion.

Observations can be:

- qualitative, if they are descriptive only. We use our senses to collect qualitative data – what we see, hear, feel, taste or smell. For example, we can observe that a substance changes colour or gas bubbles are produced.
- quantitative, if they are measured, such as mass, temperature, volume, length and time. Other quantitative measurements are concentration, pH and pressure. For example, in a chemical change we can measure the mass of the products or the changes in temperature.

When you observe chemical reactions, it is important to give reactions plenty of time as many chemical changes are slow or a second change may take place.

Paying attention when observing is the key to not missing out on any changes.



Video
Science skills in a minute: Making observations

Science skills resource
Science skills in practice: Observations to make classifications

IDENTIFYING SIGNS OF A CHEMICAL CHANGE

AIM

To record and analyse observations from various experiments to determine chemical change

INTRODUCTION

Working in a small group, conduct each of the experiments below and identify any signs of a chemical reaction. Record your observations in a table like the example shown below.

Experiment	Meniscus readings (mL)	Gas produced	Temperature reading (°C)		Precipitate	Colour change	Other
			Initial	Final			
1							
2							
3							
4							

The volume needed for each experiment varies and does not need to be exact. However, aim to get close to the approximate volume and record your meniscus reading in the table, ensuring that you estimate if the meniscus falls between graduation lines.

TIPS

- Label each test tube with the experiment number before you begin.
- Ensure your measuring cylinder is rinsed or cleaned before each experiment.

MATERIALS AND EQUIPMENT

- test-tube rack
- 5 × 25 mL Pyrex glass test tubes
- markers to label the test tubes
- thermometer

Other materials are listed within each experiment.

EXPERIMENT 1

MATERIALS AND EQUIPMENT

- 25 mL measuring cylinder
- 10 mL of 2 mol/L hydrochloric acid
- magnesium ribbon
- match and taper (for alternative option)

Safety

Treat all chemicals as toxic and avoid contact with eyes and skin. Wear safety glasses and follow any other precautions or instructions given to you by your teacher.

PROCEDURE

- 1 Use the measuring cylinder to measure approximately 10 mL of hydrochloric acid into test tube 1 and place it in the test-tube rack.
- 2 Place the thermometer into the test tube and record the initial temperature of the hydrochloric acid.

- 3 Add a curled-up 5 cm strip of magnesium ribbon to the test tube. Swirl the test tube gently and replace the thermometer.
- 4 Record the highest or lowest temperature reached after 3 minutes. Feel the test tube. Does it feel warmer or cooler?
- 5 Record all observations.

As an alternative option, conduct a hydrogen pop test.

- 1 Follow steps 1 and 3 above, skipping step 2. Place a chilled, empty test tube over the top of test tube 1, to collect the hydrogen gas produced.
- 2 Collect gas for around 1 minute, then carefully remove the top test tube, keeping it inverted.
- 3 Pass a lit taper under the opening of the removed test tube. Record all observations. Water is evidence that a new substance was produced.

EXPERIMENT 2

MATERIALS AND EQUIPMENT

- 10 mL measuring cylinder
- sodium bicarbonate
- 5 mL vinegar
- spatula

PROCEDURE

- 1 Use the clean measuring cylinder to measure 5 mL of vinegar. Pour it into test tube 2 and place it in the test-tube rack.
- 2 Place the thermometer into the test tube and record the initial temperature of the vinegar.
- 3 Use a spatula to add about half a scoop of sodium bicarbonate to the test tube.
- 4 Record the highest or lowest temperature reached. Feel the test tube. Does it feel warmer or cooler?
- 5 Record all observations.

EXPERIMENT 3

MATERIALS AND EQUIPMENT

- 10 mL measuring cylinder
- 5 mL of 0.1 mol/L solution of silver nitrate, AgNO_3
- 5 mL of 0.1 mol/L solution of potassium chloride, KCl

PROCEDURE

- 1 Using the measuring cylinder, add 5 mL of silver nitrate solution to test tube 3 and place it in the test-tube rack.
- 2 Place the thermometer into the test tube and record the initial temperature.
- 3 Using a clean measuring cylinder, add 5 mL of potassium chloride into the same test tube.
- 4 Record the highest or lowest temperature reached. Feel the test tube. Does it feel warmer or cooler?
- 5 Record all observations.

EXPERIMENT 4

MATERIALS AND EQUIPMENT

- 10 mL measuring cylinder
- 5 mL of 0.5 mol/L sodium hydroxide, NaOH
- 5 mL of 0.5 mol/L hydrochloric acid, HCl
- universal indicator solution in a dropper bottle

PROCEDURE

- 1 Use a clean measuring cylinder to add 5 mL of 0.5 mol/L sodium hydroxide to test tube 4 and place it in the test-tube rack.

- 2 Place the thermometer into the test tube and record the initial temperature.
- 3 Add two drops of universal indicator solution to the test tube.
- 4 Record your observations.
- 5 Use a clean measuring cylinder to add 5 mL of 0.5 mol/L hydrochloric acid to test tube 5.
- 6 Place the thermometer into test tube 5 and record the initial temperature.
- 7 Add two drops of universal indicator to test tube 5.
- 8 Record your observations.
- 9 Pour the contents of test tube 4 into test tube 5.
- 10 Record the highest or lowest temperature reached. Feel the test tube. Does it feel warmer or cooler?
- 11 Record all observations.

ANALYSIS (ALL EXPERIMENTS)

- 1 Analyse your data from each experiment to determine whether a chemical reaction occurred. Be sure to justify your choice by explaining your reasoning with your data.

CONCLUSION (ALL EXPERIMENTS)

Write a conclusion that summarises your findings. Make sure it relates to your aim.

16.5 Chemical reactions

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe what occurs during a chemical reaction
- ✓ describe examples of chemical reactions in everyday life.

GET THINKING

Look at diagram 16.5.1. It shows a chemical reaction. What do you think is occurring in the chemical reaction? Which part of the diagram gives you information? Consider how you might present information in diagram form as part of your written work or notes.



Video activity
Chemical reactions in 'food comas'

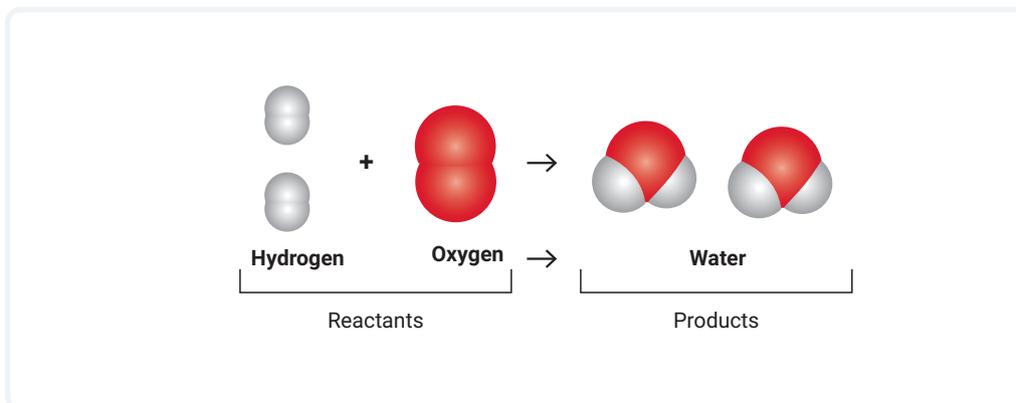
Interactive resource
Drag and drop: Signs of a chemical reaction

What happens to atoms in a chemical reaction?

During a chemical reaction, the atoms rearrange to form new substances. In chemical reactions, the number and type of atoms stay the same from the reactants to the products. The atoms are only rearranged. In Figure 16.5.1, you can see that the reactants are two hydrogen **molecules** (which have two hydrogen atoms in each molecule) and an oxygen molecule (two oxygen atoms). Molecules are structures formed by two or more non-metal atoms.

Count the number of hydrogen and oxygen atoms in the reactants. Now count the atoms in the products. What do you notice? The two sides of the chemical reaction have the same number of the same type of atom. In this case, both reactants and products have 4 hydrogen atoms and 2 oxygen atoms. That's because in a chemical reaction, it is only the arrangement of atoms that changes.

molecule
two or more non-metal atoms bonded together



▲ FIGURE 16.5.1 The reaction of oxygen and hydrogen to form water is a chemical reaction.

Examples of chemical reactions

Almost everything that you come into contact with was made by a chemical reaction. You observe hundreds of reactions a day; they even occur constantly inside your body!

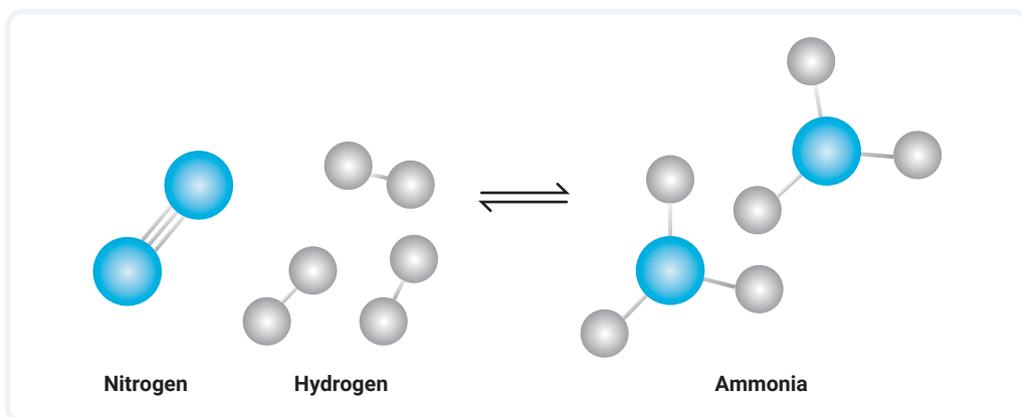
One of the places you are most likely to encounter a chemical reaction is food. Most food is made through chemical reactions. The baking powder in bread, cakes, biscuits and pastries reacts to produce carbon dioxide, which makes them rise (Figure 16.5.2). Cooking food such as eggs or steak causes sugars and proteins to break down and form new compounds with different flavours. Even a salad begins with a chemical reaction, because plants form sugars through a chemical reaction called photosynthesis.



Praitsaeng/Shutterstock.com

▲ FIGURE 16.5.2 Baking involves chemical reactions.

Another example is the making of the cleaning chemical ammonia, produced in a chemical reaction. Nitrogen and hydrogen gases are combined to form ammonia, as seen in Figure 16.5.3.



▲ FIGURE 16.5.3 Ammonia is formed when nitrogen and hydrogen gas combine.

Other chemical reactions you might be familiar with are the:

- discharging and recharging of batteries in your phone and laptop
- production of plastics, polymers and most fibres you wear (e.g. nylon)
- production of concrete, paints, glues and many other building and construction materials.

Observing a chemical reaction – elephant's toothpaste

Follow the instructions below to set up a spectacular chemical reaction. In this reaction the reactant is hydrogen peroxide (containing hydrogen and oxygen). The products are water and oxygen. The experiment also uses yeast as a catalyst. A catalyst is a chemical that helps speed up a chemical reaction but does not take part in the chemical reaction.

This experiment can be messy. It is recommended that you do it outside, in a large sink or trough, or on a tarpaulin.

Procedure

- Pour 125 mL of 6 per cent hydrogen peroxide into a clean, dry, 1.25 L plastic drink bottle.
- Add 1–2 mL of dishwashing detergent (to create bubbles) and 1 mL of food colouring.
- Place a sachet of yeast (e.g. baker's yeast) into a 250 mL beaker and add 50 mL of warm water. Stir for 30 seconds.
- Place the 1.25 L bottle onto a tarpaulin, or in a sink to catch the overflow. Place a funnel in the top of the bottle.
- Pour the yeast solution into the bottle, quickly remove the funnel and move away!

Analysis

- 1 What observations did you make that tell you this was a chemical reaction?
- 2 Identify the reactants and products in this chemical reaction.
- 3 A molecule of hydrogen peroxide has two hydrogen atoms and two oxygen atoms. Explain how many oxygen and hydrogen atoms must be in the products if a single molecule of hydrogen peroxide reacts.

16.5 LEARNING CHECK

- 1 **Identify** four observations that provide evidence of a chemical reaction occurring.
- 2 **Describe** five chemical reactions you have already come into contact with, seen or used today. Consider what you have eaten, how you got to school, what you are wearing or what you are using.
- 3 **Compare** what happens to particles during a physical change, such as melting, with what happens to atoms during a chemical change, such as that shown in Figure 16.5.1.

16.6 Energy change in a reaction

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ analyse data to provide evidence that a chemical change has occurred
- ✓ explain how differences in temperature indicate that a chemical change has occurred.



Video activity
Energy change
of reactions

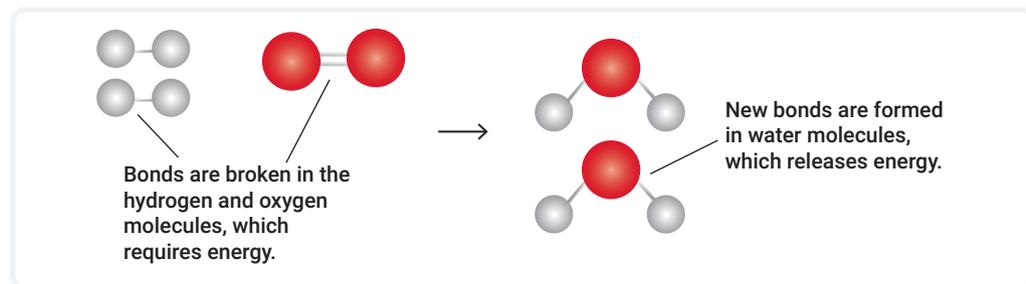
GET THINKING

Have you ever wondered why a cold pack in a first aid kit becomes cold so quickly, after simply snapping it? That is an example of an endothermic reaction working for us!

Energy in a chemical reaction

When a chemical reaction occurs, bonds between reactant atoms break. When the products form, new bonds form between atoms to make new molecules or compounds. For a reaction to occur, energy is needed to break the bonds between the reactants (Figure 16.6.1). Put simply, chemical bonds store energy. Stored energy is called potential energy. Energy stored in the chemical bonds of a substance is called **chemical potential energy**. Chemical potential energy:

- allows animals, such as humans, to obtain energy from the chemical reactions that occur in digesting food
- is released by batteries
- produces energy when fossil fuels are burned.



▲ FIGURE 16.6.1 Bonds are broken and remade in the formation of water.

endothermic reaction
a chemical reaction that takes in heat energy



Alamy Stock Photo/Sibag

▲ FIGURE 16.6.2 An instant cool pack is an example of an endothermic reaction.

Heat is a form of energy

Chemical reactions involve either absorbing or releasing energy. Chemical reactions that absorb energy in the form of heat are called **endothermic reactions**. These reactions take in heat from the surroundings, and that heat is used as the energy for the reaction to occur. In this type of reaction, the temperature will drop. A common example is the instant cool pack found in first aid kits (Figure 16.6.2). When the pack is squeezed, the inner bag of water is broken, and the water dissolves the solid in the pack. The process absorbs heat from the surroundings, which lowers the temperature of the pack.

Chemical reactions that release energy are called **exothermic reactions**. These reactions give off energy in the form of heat. Their temperature increases. A common example is burning fuels like wood or coal.

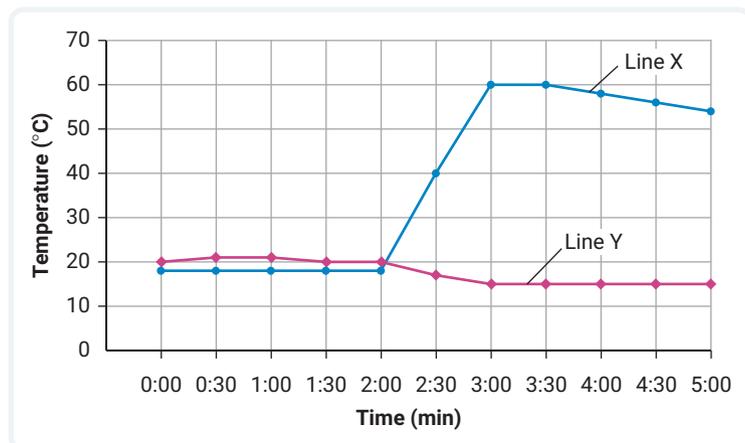
exothermic reaction
a chemical reaction that releases heat energy

Interpreting data for change in heat

Consider a classroom experiment using two different chemicals: chemical A and chemical B. Chemical A combines with water in an endothermic reaction and chemical B combines with water in an exothermic reaction.

The experiment

Each chemical was mixed in a different beaker with the same volume of water. A thermometer was used to measure the temperature of the water before and after the chemical and water were mixed. The data was graphed as shown in Figure 16.6.3. Can you tell which line represents chemical A? Which line represents chemical B?



▲ **FIGURE 16.6.3** Temperature change during an experiment using two different chemicals

Analysing the data

Both solutions remained at a constant temperature, around 20°C, for the first 2 minutes. Then, the temperature of one of the solutions (line X) rose from 20°C to 60°C over 1 minute while the temperature of the other solution (line Y) dropped from 20°C to 15°C in the same amount of time. Line X showed an increase in temperature, meaning it was an exothermic reaction. Therefore, chemical B is represented by line X. Line Y showed a decrease in temperature, meaning it was an endothermic reaction. Therefore, line Y represents chemical A.

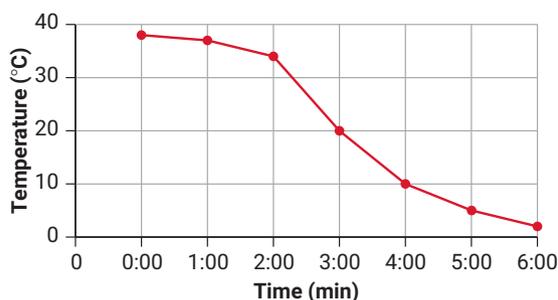
DATA SCIENCE



Learn more about interpreting data for trends in **Module 2.8**.

16.6 LEARNING CHECK

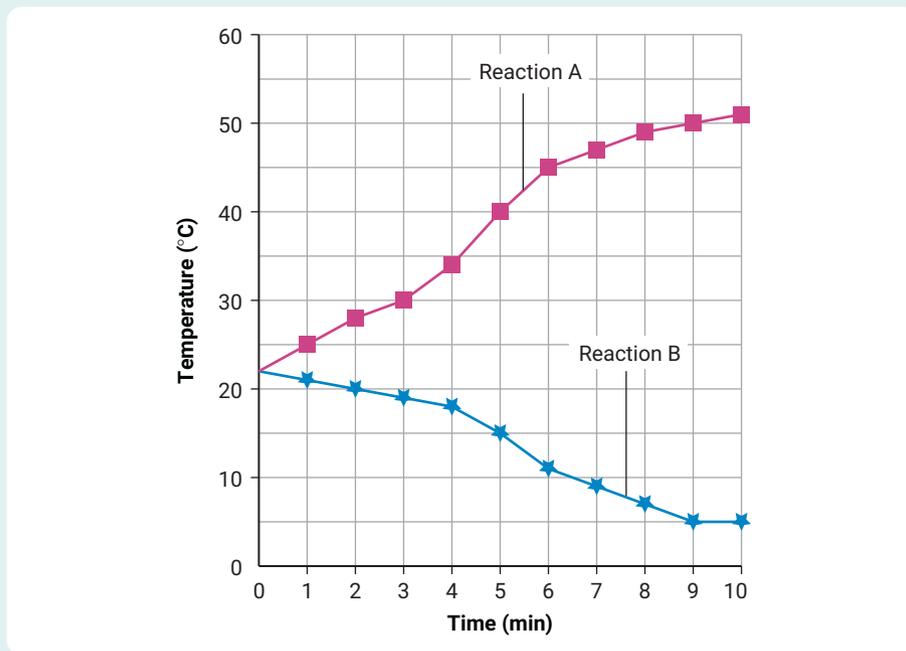
- 1 Recall** whether an endothermic reaction or an exothermic reaction releases heat energy.
- 2 Explain** how, during a chemical reaction, a change in energy could be measured.
- 3** Below is a graph showing temperature change during a chemical reaction. Is the reaction endothermic or exothermic? **Explain** your reasoning.





4 **Analyse** the graph below to answer the following questions.

- a At what time does reaction A reach 40°C?
- b What temperature is the mixture in reaction B at 3 minutes?
- c What is the initial temperature for both reactions?
- d Classify each reaction as endothermic or exothermic. Justify your answer.



5 **Analyse** the exothermic reaction data in the table below and do the following.

- a Fill in the missing data with approximate values.
- b **Calculate** the temperature change for the reaction.

Time (min)	Temperature (°C)
0	22
2	
	26
6	28

- c **Construct** a graph using the data from your completed table. The x-axis should be time (independent variable); the y-axis (dependent variable) should be temperature.
- 6 **Recall** three ways chemical potential energy plays a role in everyday life.

**SCIENCE SKILLS IN FOCUS**

IN THIS MODULE, YOU WILL FOCUS ON
LEARNING AND IMPROVING THESE SKILLS:

- ▶ making and recording observations to make inferences about chemical change
- ▶ investigating the process of respiration and observing chemical change
- ▶ modelling the process of photosynthesis to show indicators of chemical change.

Scientists make observations during experiments. Observations are things you can see. In experiments, this typically includes colour changes, formation of bubbles, a solid forming or dissolving, a change of state or a change of volume. There are many other observations you can make; these are just a few examples.

Observations can help you make an inference. An inference is a conclusion you make based on observations and your knowledge of the relevant theory.

For example, you might observe that bubbles of gas form during a particular chemical reaction. You know from your chemistry studies that when you add these two particular chemicals together, you expect hydrogen gas to form. Therefore, you can infer that hydrogen has formed during the reaction. It would be incorrect to say you observed hydrogen forming because you cannot observe this: hydrogen is an invisible gas. You only infer this from the signs (the bubbles) you observe.

You should review the signs of chemical change before you start this experiment so you know which observations you should be making, and which observations are not relevant to the aim of the experiment.

**MODELLING CELLULAR
RESPIRATION****AIM**

To observe signs of chemical change in the cellular process of respiration. To review the process of cellular respiration, see Module 7.5.

BACKGROUND INFORMATION

Cellular respiration occurs inside cells in most organisms. It is the conversion of glucose (sugar) and oxygen into carbon dioxide and energy. Yeast are simple micro-organisms that carry out cellular respiration in the presence of sugar. In this experiment, the yeast release carbon dioxide gas as they convert the sugar.

MATERIALS AND EQUIPMENT

- 5 g yeast
- 10 g sugar
- 250 mL conical flask
- balloon
- 50 mL water, heated to 35°C (you could use a hot plate for this, so it heats gently)
- electronic scale

PROCEDURE

- 1 Using an electronic scale, measure 5 g of yeast and 10 g of sugar in separate weighing dishes.
- 2 Measure approximately 50 mL water into a 250 mL conical flask.
- 3 Place the yeast and sugar into the conical flask and swirl to mix.
- 4 Place the balloon over the top of the conical flask so the gas that forms is collected.
- 5 Leave for 10 minutes (or until the balloon fills – do not let the balloon burst). At the end of the 10 minutes, take the balloon off and let the gas escape carefully.
- 6 During the 10 minutes the reaction is occurring, look for signs of chemical change. Record them in a suitable format. You might make a table, take photographs or a video, record a written description or make a labelled diagram.

RESULTS

Record your results in a suitable format as suggested in step 6 of the procedure.

ANALYSIS

- 1 Describe the observations you made that indicated that cellular respiration is a chemical change.
- 2 What inferences can you make about cellular respiration based on these observations?
- 3 Were there any observations you made that indicated a physical change had occurred? Suggest why these may have occurred.
- 4 Using the information from Chapter 7 on photosynthesis, create a model to describe the energy changes that occur and predict the indicators of chemical change you would observe. Your model can be a physical model, drawing, computer animation, slideshow, or other medium you choose.

16.8 Writing word and chemical equations

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ write word equations to represent chemical reactions
- ✓ identify the reactants and products in a word equation
- ✓ recognise and interpret the information in a chemical equation.

GET THINKING

Have a look at the word and chemical equations in this module. In what ways are they similar to maths equations? In what ways are they different? Based on your maths knowledge, what do you think these equations are telling you?



Interactive resource
Match: Word equations

Features of equations

Throughout your chemistry studies, you have often seen chemical reactions represented in words. For example, in Module 16.6, you looked at the chemical reaction involving hydrogen and oxygen forming water. The **word equation** for this reaction is:



A word equation has the following features.

- All reactants are on the left side of the equation.
- All products are on the right side of the equation.
- An arrow points from the reactants to the products.

word equation

a word summary that shows the reactants and products of a chemical reaction

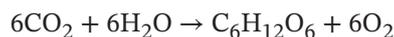
Steps in writing a word equation

The steps to writing a word equation are as follows.

- 1 Write the reactants with a + sign between each reactant. For example, 'hydrogen + oxygen'.
- 2 Put an arrow after the reactants, then write the products with a + sign between each product.
- 3 Put any conditions required over the arrow.
- 4 Include state symbols for each reactant and product, as described later in this module.

Chemical equations

A **chemical equation** gives the same information as a word equation, except it uses chemical formulas instead of chemical names. The chemical equation for photosynthesis is:



chemical equation

a symbol summary that shows the reactants and products of a chemical reaction

The numbers in front of the chemical symbols are known as coefficients. They show how many atoms or molecules are needed or produced in a chemical reaction. You will learn more about coefficients in your Stage 5 studies.



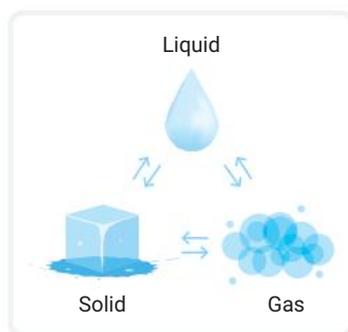
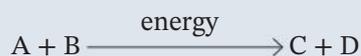
▲ FIGURE 16.8.1 A sparkler needs energy to start a chemical reaction.

conditions

factors that affect a chemical reaction, such as heat or pressure

Showing conditions in chemical equations

A chemical equation shows the chemicals involved in the reaction. Sometimes other factors are involved that are not chemicals. For example, some chemical reactions need heat or energy to start them, or they produce energy (Figure 16.8.1). Other factors that affect chemical reactions are pressure or use of a catalyst to speed up the reaction, as you saw in the elephant's toothpaste activity in Module 16.5. So how can we show these other factors? We call these other factors **conditions** and can put them over the arrow in the equation:



▲ FIGURE 16.8.2 Water can exist as a solid, a liquid and a gas.

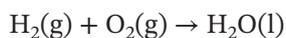
Describing the state of a chemical

Sometimes it is helpful to identify the state of a chemical. Water can exist as a solid (ice), a liquid (water) and a gas (steam) (Figure 16.8.2). When water is a reactant or product, sometimes it is a liquid, and sometimes a gas. Instead of writing 'water (gas)' or 'steam' (steam is not a chemical name), you can use state symbols.

State symbols are written in brackets after a substance to show whether it is solid (s), liquid (l), gas (g) or dissolved in water as a solution (aq). The 'aq' for a solution represents **aqueous**. An aqueous solution is a substance that is dissolved in water. Pure water with nothing dissolved in it is not aqueous; it is a liquid.

aqueous

describes a solution that is a substance dissolved in water



☆ ACTIVITY

Writing word equations from chemical experiments

You will perform four chemical reactions and practise writing word equations. You will also make observations that show a chemical reaction has occurred.

For each reaction:

- conduct the experiment as described
- use the information provided to write a word equation, including states and any other conditions required
- record observations that show a chemical reaction has occurred

⚠ Safety

Chemicals can cause skin irritation or more severe problems if swallowed or they get into your eyes. Wear appropriate PPE (gloves, safety glasses and lab coat) to protect yourself.

Check with your teacher about how to dispose of the chemicals you use.

Observations are what you can see, not conclusions or assumptions. So, you cannot observe 'hydrogen gas forming', you can only observe 'bubbles of gas forming'.

Follow the instructions below, record your results, and then answer the questions.

Procedure

Chemical reaction 1: magnesium metal and hydrochloric acid

- In a 100 mL conical flask, add 20 mL of 1.0 mol/L hydrochloric acid solution to a 3 cm strip of magnesium metal.
- The products of this reaction are magnesium chloride solution and hydrogen gas.

To give you another example of a chemical equation, reaction 1 is shown below:



Chemical reaction 2: copper sulfate solution and sodium hydroxide solution

- In a micro test tube (or the smallest test tube you have) add 10 drops of 0.25 mol/L copper sulfate solution to 10 drops of 0.25 mol/L sodium hydroxide solution.
- The products of this reaction are copper hydroxide solid and sodium sulfate solution.

Chemical reaction 3: hydrochloric acid and sodium hydroxide

- In a micro test tube (or the smallest test tube you have) add 10 drops of 0.25 mol/L hydrochloric acid solution to 10 drops of 0.25 mol/L sodium hydroxide solution.
- The products of this reaction are sodium chloride solution and liquid water.

Chemical reaction 4: methane and oxygen

- Light a Bunsen burner and turn it to a blue flame. The Bunsen burner gas is methane, and it burns in the oxygen in the air.
- The products of this reaction are carbon dioxide and water.

Analysis

- 1 Did all the chemical reactions show obvious signs of a chemical change occurring? Use specific examples from the four experiments in your answer.
- 2 Did any of the four reactions you performed require heat to start?

16.8 LEARNING CHECK

- 1 **Identify** the different states that can be included in a chemical equation and why they might be necessary.
- 2 How are conditions such as temperature and pressure represented in a chemical equation? Why is this?
- 3 **Write** word equations for the following. **Include** states and reaction conditions if they are appropriate.
 - a Solid pieces of calcium react with oxygen gas when heated to form solid calcium oxide.
 - b Hydrogen peroxide (liquid bleach) decomposes when heated to form oxygen gas and liquid water.
 - c Copper nitrate solution and sodium hydroxide solution combine to form solid copper hydroxide and a solution of sodium nitrate.

16.9

Use of chemical and physical changes

IN THIS MODULE, YOU WILL:

- ✓ explore Aboriginal and Torres Strait Islander Peoples' use of physical and chemical changes.

Joe Sambono



▲ **FIGURE 16.9.1** Many Aboriginal and Torres Strait Islander Peoples have sustainably harvested grass tree resin over thousands of years.



Dr Joanna Sundstrom, University of Adelaide

▲ **FIGURE 16.9.2** Scientists from the University of Adelaide and Australian Wine Research Institute collect sap from the Tasmanian cider gum (*Eucalyptus gunnii*). This sap has traditionally been used to produce a fermented drink called *wayalinah*.

Resins

Before colonisation, Aboriginal and Torres Strait Islander Peoples observed and experimented with natural substances. This experimentation led them to develop many sophisticated chemical processes, which allowed them to produce required substances that were either scarce or unavailable.

Resins are produced by plants. Resins were, and still are, widely used by Aboriginal and Torres Strait Islander Peoples as adhesives for manufacturing and repairing tools. The type of resin depends on the plant source and its availability. Heating makes the resin soft and malleable. This allows it to be easily applied to the surfaces that are to be cemented together. Once the resin has cooled, the surfaces are firmly bound together. If a tool requires repair, the resin holding the parts together can be reheated and reshaped. The parts are put back into position and the resin is left to cool and harden again. If too much heat is applied to the resin, it will become brittle when it cools and cannot be resoftened. The resin would burn if it becomes too hot.

Resins and gums from plants could also be burned to produce fire for burning Country, or to provide light at night. Records show that on Yidinjdji country in the Cairns–Yarrabah area of northern Queensland, a form of slow-burning torch was made by coating a branch with resin from the black kauri pine and setting it alight.

Fermentation

Aboriginal and Torres Strait Islander Peoples developed fermentation processes using native yeasts and bacteria, sugar-rich saps and nectars to produce alcoholic drinks. For example, cider gum, a Tasmanian eucalypt, provided a sugar-rich sap used by the Palawa People to produce a fermented drink, while the Noongar People from southwestern Western Australia used nectar from certain banksia species to produce their drink.

Pyrolysis

Pyrolysis is the process of heating plant material to very high temperatures, without oxygen. The plant material gets so hot that it breaks down. Aboriginal and Torres Strait Islander Peoples used pyrolysis to produce numerous important substances.

- Some Aboriginal Peoples in central Australia developed a medicine that helped people when travelling long, difficult journeys. They found that the addition of quicklime (calcium oxide) increased the effectiveness of the medicine. Aboriginal Peoples used pyrolysis of plants high in calcium oxide to produce the required quicklime ash.
- Charcoal was produced for use in pigments and added to adhesives.
- Pyroligneous acid was made by some Palawa women of Tasmania and used to dissolve the thin outer coating on *marina* shells. This exposed the highly iridescent layer underneath. The shells were then used to make necklaces and other jewellery (Figure 16.9.3).
- Wood ash was produced from plants high in sodium and potassium and was used as a substitute for sea salt (sodium) by Aboriginal Peoples living far from the sea. They understood that sodium was vital for many physiological processes.



Joe Sambono

▲ FIGURE 16.9.3 A *marina* shell bracelet made by Palawa Elder Jeanette James Lutrawita (Tasmania)

Draw up a table with the headings given below. Add several blank rows below the heading row. Use the information provided in this module to identify at least four different processes involving physical and/or chemical changes.

☆ ACTIVITY 1

Starting substance (reactant)	Product(s)	Process	Chemical or physical change?	Reason

Plaster

Historical records show Aboriginal Peoples producing plaster for toys, games and body ornamentation. They used a process of controlled heating (called calcination) to change the naturally occurring gypsum (calcium sulfate) into plaster. Aboriginal Peoples understood the importance of carefully controlling the amount of heat in the production of plaster. They knew that if too much heat was used, the final product would not set after water was added. Records also show the production of pigments for paints using the same method.



Joe Sambono

▲ FIGURE 16.9.4 Aboriginal Peoples used controlled heating (calcination) to change gypsum into plaster.

☆ ACTIVITY 2

In this investigation you will compare the physical and chemical properties of gypsum before and after calcination to determine whether a physical or chemical change has occurred.

Safety

Wear safety glasses and protective equipment. Do not touch hot equipment with bare hands. Follow your teacher's instructions about disposal of waste material.

Materials and equipment

- 15 g gypsum
- electronic balance
- mortar and pestle
- crucible and tongs
- pipe clay triangle
- Bunsen burner and tripod
- 6 test tubes
- test-tube rack
- spatula
- distilled water
- 10 mL of 0.5 mol/L hydrochloric acid
- matches

Procedure

- 1 Place 15 g of gypsum in a mortar and pestle and grind it to a powder.
- 2 Record the physical properties of the powder produced.
- 3 Place a small spatula of the powder in each of three test tubes in a test-tube rack and label the test tubes 'Gypsum 1', 'Gypsum 2' and 'Gypsum 3'. Ensure there is enough powder left for the next step.
- 4 Place the remaining powder in a crucible, and then place the crucible on a pipe clay triangle on a tripod over a Bunsen burner.
- 5 Light the Bunsen burner, turn it to a blue flame and heat the powder for 2–3 minutes.
- 6 Turn off the Bunsen burner and allow the crucible and product to cool.
- 7 Record the physical properties of the product.
- 8 Place a small spatula of the product in each of three test tubes in a test-tube rack and label the test tubes 'Product 1', 'Product 2' and 'Product 3'.
- 9 One-third fill each test tube labelled '2' (Product and Gypsum) with distilled water, and shake it gently to mix. Feel the test tubes. Record your observations.
- 10 One-third fill each test tube labelled '3' (Product and Gypsum) with hydrochloric acid, and shake it gently to mix. Feel the test tubes. Record your observations.
- 11 Compare the appearance of the substances in the test tubes labelled '1' (Product and Gypsum). Record your observations.

Analysis

- 1 Review all your observations and determine whether the calcination of gypsum results in a physical or a chemical change. Support your decision with evidence from your observations.
- 2 **Suggest** how you could determine whether the gypsum had been overheated in the investigation, producing an unusable product.

16.10 Biodegradable materials

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ explain how science communication has helped the community form views on the use of biodegradable materials.

Some takeaway restaurants have replaced plastic straws with cardboard straws, and plastic forks, knives and spoons with wooden eating utensils. Some shopping outlets have eliminated single-use plastic bags. Do you know why?

Single-use plastics are being replaced because of their harmful environmental impact. They don't readily break down and they contaminate land and the oceans. You may have read about this topic or had discussions about it with others. Talking, raising awareness, or even arguing about science-related topics is called **science communication**.

In 2021, the Australian Government released a plan for industry to phase out the use of single-use non-recyclable plastic. This includes plastics that, if littered, have a negative environmental impact. The government published the policy, raised awareness and advocated for the policy. These were forms of science communication.

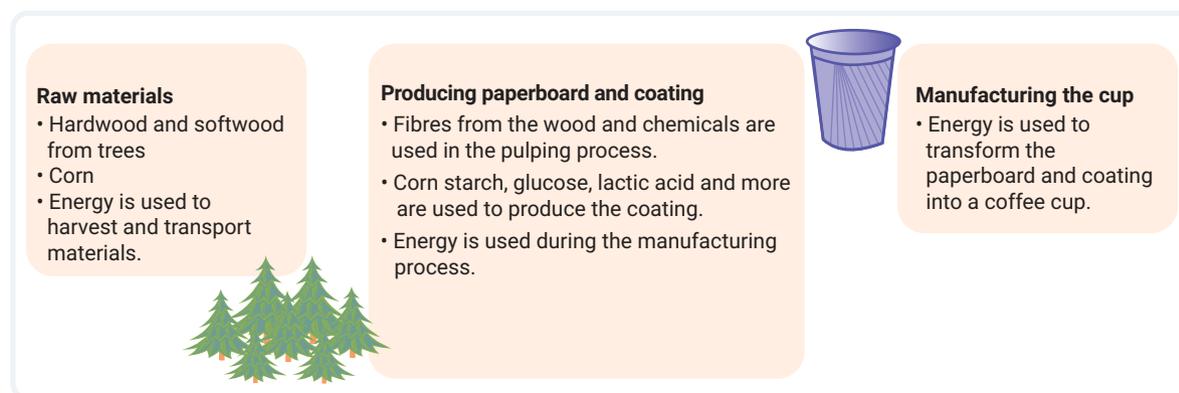
Single-use plastics have been replaced with similar products made of **biodegradable** materials. Biodegradable means the product completely breaks down and returns to natural products within a short time – typically a year or less. Items such as cardboard straws and wooden utensils break down or degrade naturally, molecule by molecule. The smaller pieces can assimilate back into the environment because they have the same composition as the natural material that they were made from; for example, timber.



Video activity
Biodegradable plastic

science communication
talking, raising awareness or even arguing about science-related topics

biodegradable
describes a substance or product that is able to completely break down and return to natural products within a short time



▲ FIGURE 16.10.1 What natural products go into making a biodegradable coffee cup?

16.10 LEARNING CHECK

- 1 Biodegradable plastics also exist. This photo shows an example of this. **Research** the following claim: 'Bioplastic cups are better for the environment than plastic cups.' Ensure the research reports you base your answer on use data.
- 2 Think and make notes about your viewpoints on biodegradable materials and **discuss** them with your classmates.



GIPHOTOSTOCK/Science
Photo Library

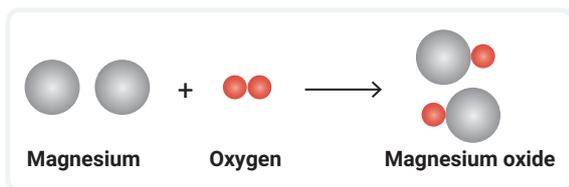
16 REVIEW

REMEMBERING

- 1 **Recall** where the energy that is released during a chemical reaction is stored.
- 2 **Recall** whether the products or reactants are on the left side of the arrow in a chemical equation.
- 3 **Define** precipitate.

UNDERSTANDING

- 4 **Imagine** that you could see the atoms moving around as a substance changed appearance. **Describe** how you would know whether the process is a physical or a chemical change.
- 5 **Imagine** tearing a piece of paper in half, putting the halves on top of each other, and then tearing them again. If you repeated this again and again, the paper pieces would get smaller but the stacks would get thicker. **Explain** whether this is a physical or chemical change.
- 6 **Classify** each of the characteristics as representative of a chemical or physical change.
 - a It is easily reversed.
 - b The components can be separated by physical means; for example, sifting.
 - c It involves breaking bonds and forming new bonds between atoms.
 - d New chemical substances are formed.
- 7 **Explain** the difference between an observation and inference.
- 8 **Discuss** what is happening in the diagram below.



- 9 Using a particle diagram, **explain** why ice melting to become liquid water is a physical change.
- 10 **Explain** why a difference in temperature can indicate that a chemical reaction has occurred.

APPLYING

- 11 The following observations were made during a class experiment.
 - A brown solid changed shape at 35°C when touched.
 - The solid became a liquid at 49°C.
 - When the solid was added to the red liquid, it bubbled and let off a strong odour.
 - a **List** the signs of physical change in this experiment.
 - b **List** the signs of chemical change in this experiment.
- 12 Chemical A was combined with Chemical B. The observations are recorded below. For each of the three examples, **explain** whether you think a chemical change has occurred, and why.

	Chemical A	Chemical B	Products
a	Clear solution	Clear solution	Cloudy and milky
b	Clear solution	Clear solution	Clear solution
c	Clear solution	Pale orange solution	'Blood red' solution

- 13 Two unknown solutions are combined and observed. The data is shown below. **Identify** whether a chemical reaction occurred and explain why or why not.

	Chemical A	Chemical B	Product
Colour	Red	Blue	Two layers: one red and one blue

ANALYSING

- 14** Simon mixed two chemicals in a flask and placed the flask on an electronic balance that had already been zeroed for the mass of the flask. Simon measured the combined mass of the substances every minute for 7 minutes. He observed bubbles on the surface of the combined substances throughout the experiment. The table below shows the data he collected.

Time (minutes)	Mass of two substances (g)
0	10.0
1	9.9
2	9.7
3	9.6
4	9.5
5	9.5
6	9.4
7	9.3

- a** Use the data in the table above to **construct** a line graph.
- b** **Identify** the trend in the data by describing what is happening to the mass as time increases.
- c** **Calculate** the change in mass over 7 minutes.
- d** Use your graph to **estimate** (interpolate) the mass at 3.5 minutes.
- e** Use your graph to **estimate** (extrapolate) the mass of substance that would remain after 8 minutes.
- f** **Justify** whether this experiment represents a physical or a chemical change.
- 15** The table at the bottom of the page shows the observed results of four experiments. The experimenter marked a cross when she observed each listed item. The absence of a cross means that phenomenon was not observed. **Determine** which experiment(s) resulted in chemical change.

Experiment	Bubbles and/or smell	Colour change	Temperature change	Precipitate
1	X		X	
2				X
3				
4		X		

- 16** **Compare** and **contrast** the terms 'chemical change' and 'chemical reaction'.

- 17** Look at the image, then answer the questions.

- a** **Describe** the signs of physical and chemical change you observe when a sparkler is lit.
- b** **Explain** why lighting a sparkler is an example of chemical reaction.
- c** Is this reaction endothermic or exothermic? Provide three examples of this type of chemical reaction.



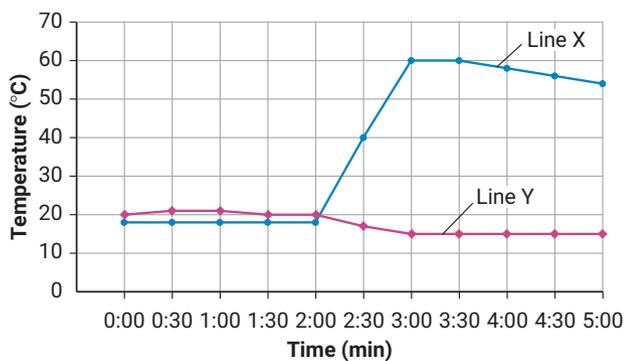
- 18** Aboriginal Peoples used the processes of pyrolysis and calcination to produce important substances. **Compare** these two processes, **identifying** the physical and/or chemical changes involved.

EVALUATING

19 During the recycling process for aluminium, which can occur an infinite number of times, the aluminium goes through several physical changes. The stages are listed below, out of order. **Determine** the correct order and **rewrite** the steps.

- A Chips are melted and re-formed into solid blocks of aluminium.
- B Bales are cut and smashed into small aluminium chips.
- C Blocks are pressed and rolled into thin aluminium sheets.
- D New cans are cut and moulded.
- E Empty, used cans are collected by people.
- F Used cans are crushed and formed into large cubic bales.

20 The figure below shows the results of classroom experiments using two chemicals, X and Y. Use the information and the figure to answer the questions.



The chemicals: Chemicals X and Y are different chemicals. Each is mixed with water.

Classroom experiment: Each chemical was mixed with water in a different beaker, using the same volume of water. A thermometer was used to measure the temperature of the water before and after the chemical and water were mixed.

- a **Describe** what is happening in the experiment in Line X.
- b **Describe** what is happening in Line Y.
- c Which one of these lines represents an exothermic chemical reaction? **Explain** your reasoning.

CREATING

21 Construct a flow chart using the following terms: solid, liquid, gas, melting, freezing, condensing, evaporating, subliming.

1 Connect what you've learned

In this chapter, you've learned about chemical reactions and indicators that chemical changes have occurred. Create a mind map to show how the information you have learned is connected.

2 Check your thinking

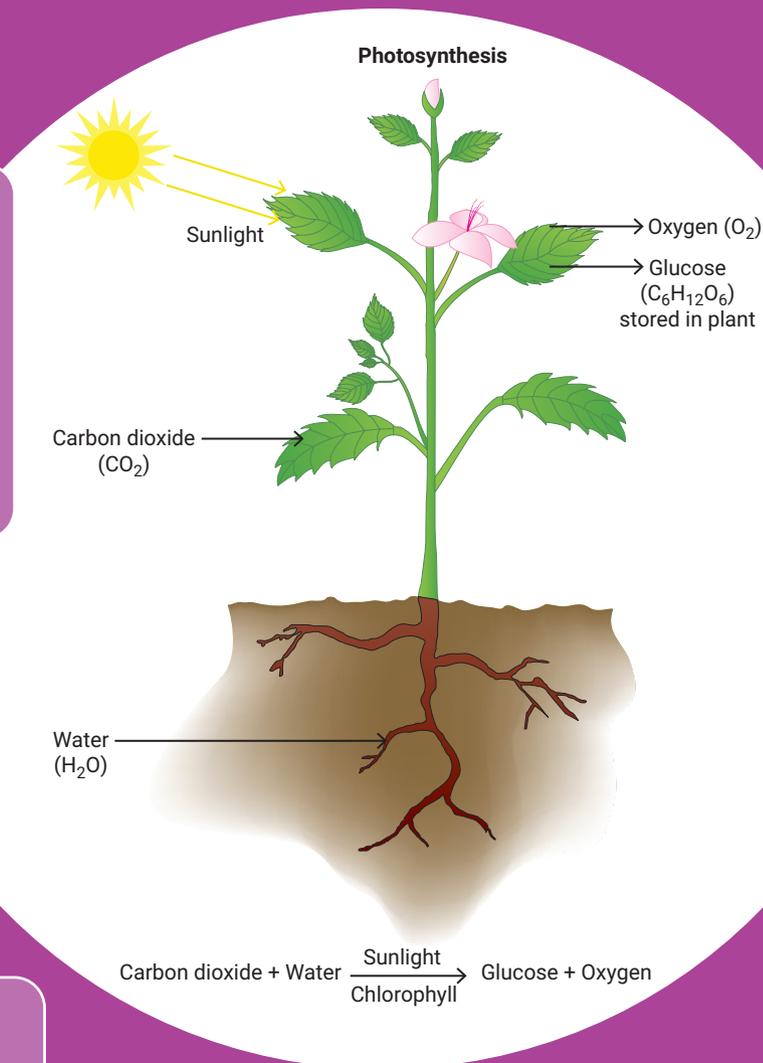
- Explain, in terms of chemical change, what happens during photosynthesis.
- Examine the reactants and products and think about how this chemical reaction decreases the pollutant carbon dioxide, CO_2 , while producing oxygen.
- What evidence is present during photosynthesis to indicate that a chemical change is occurring?
- Use your answers to deduce why tropical rainforests are called the 'lungs of the planet'.

3 Get into action

Conduct research into the claim that photosynthesis is one of the most important chemical reactions on Earth.

4 Communicate

Use your knowledge and understanding to create a persuasive text addressing the above claim. Your text should contain data from a reliable source.



17

Plate tectonics

17.1 The structure of Earth (p. 590)

Earth is composed of layers with different compositions and properties.

17.2 Plate tectonics (p. 592)

The plate tectonics model explains how surface features of Earth are created.

17.3 Plate boundaries (p. 596)

Plates interact with each other in different ways.

17.4 WORKING SCIENTIFICALLY: Modelling tectonic plate movement (p. 599)

Cheesy plate tectonics

17.5 Evidence for plate tectonics (p. 600)

The plate tectonics model is supported by physical and geological evidence.

17.6 WORKING SCIENTIFICALLY: Using maps to present scientific data (p. 602)

Using maps to summarise information and show patterns

17.7 Continental drift (p. 604)

Continental drift describes how the continents move.

17.8 Seafloor spreading (p. 606)

New ocean floor is created by a process called seafloor spreading.

17.9 WORKING SCIENTIFICALLY: Cause-and-effect models (p. 610)

Modelling seafloor spreading

17.11 ABORIGINAL AND TORRES STRAIT ISLANDER SCIENCE CONTEXTS: Records of geological events in Australia (p. 616)

Knowledge of geological events has been passed from generation to generation of Aboriginal and Torres Strait Islander Peoples through their oral traditions.

17.10 Earthquakes and volcanoes (p. 612)

Earthquakes, volcanoes and tsunamis are generated by tectonic processes.

17.12 SCIENCE IN CONTEXT: Discovering the ocean floor (p. 618)

Our understanding of plate tectonics and how the seafloor forms and changes has evolved over time.



▲ FIGURE 17.0.1 A volcanic landscape in Iceland

In some parts of the world, such as Iceland, it is easy to see Earth's surface being shaped by enormous forces.

What do you see in Figure 17.0.1? Why do the hills in the distance have a cone shape? Why is the valley so broad and flat? Why is the ground composed of dark rocks?

- Why is the Icelandic landscape so different from that of Australia?

#17 DIVE INTO SCIENCE!

At the end of this chapter, you can complete Science in Depth Study #17. You can use the information you learn in this chapter to complete the project.

Assessments

- Prior knowledge quiz
- Chapter review questions
- End-of-chapter test
- Depth study: Research project

Videos

- Science skills in a minute: Presenting data in different forms (17.6)
- Video activities: Structure of Earth (17.1); Plate tectonics (17.2); The scientist behind the plate tectonics theory (17.7); What is a volcano? (17.10); What is an earthquake? (17.10); Mapping the secrets of the ocean floor (17.12)

Science skills resources

- Science skills in practice: Data in different forms (17.6)
- Extra science investigation: Modelling P and S waves (17.10)

Interactive resources

- Label: Earth's structure (17.1); Features of plate boundaries (17.3); Features of the seafloor (17.8)
- Drag and drop: Convection currents and slab pull (17.2)
- Match: Types of boundaries (17.3)
- Quiz: Evidence for plate tectonics (17.5); Seafloor magnetic patterns (17.8)

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

✓ describe the layered structure of Earth.



Video activity
Structure of Earth

Interactive resource
Label: Earth's structure

geosphere

the solid part of Earth

atmosphere

the gaseous layer surrounding Earth

hydrosphere

all the water on Earth

biosphere

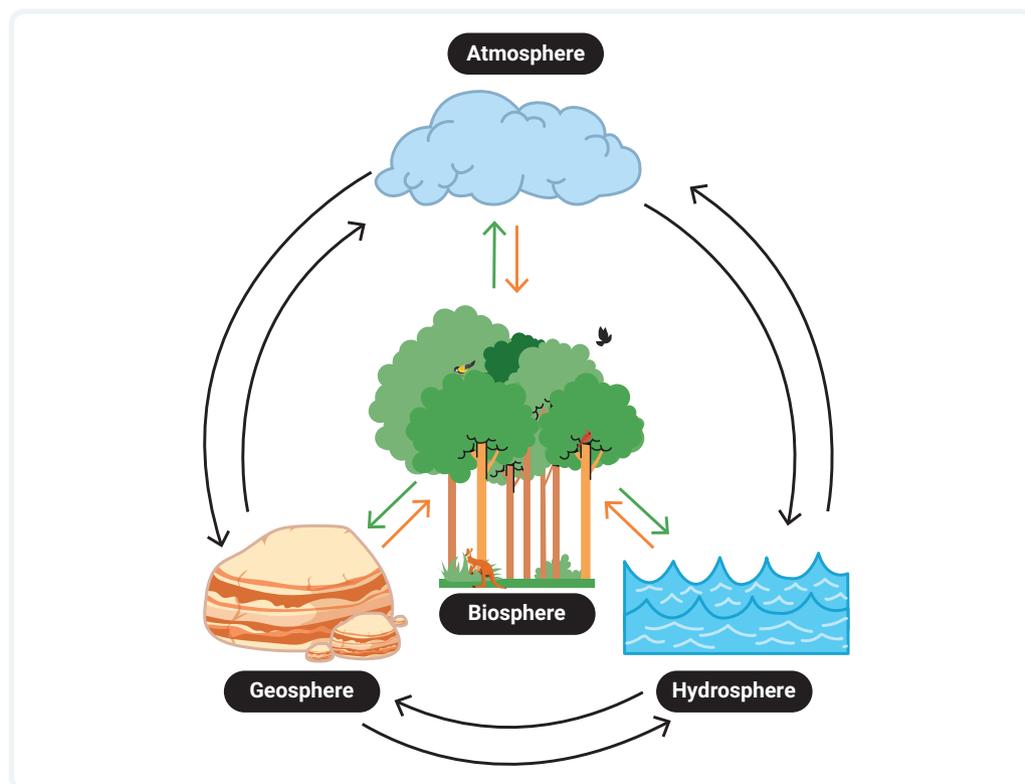
the parts of Earth where life is found

GET THINKING

How many layers make up Earth? Which is the largest? Survey the module and see whether you can count how many layers there are.

Earth system

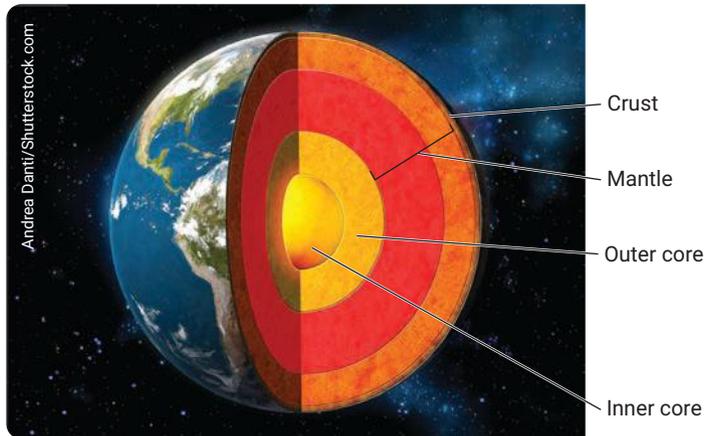
Earth is composed of four spheres that interact with each other to form the 'Earth system' (Figure 17.1.1). The solid Earth is referred to as the **geosphere**. The gaseous envelope surrounding Earth is the **atmosphere** and all the water on Earth forms the **hydrosphere**. Life occurs in all the outer layers of Earth, including deep in the crust. The **biosphere** is all the places where life is found.



▲ FIGURE 17.1.1 Earth's four spheres interact with each other.

The geosphere

As you learned in Module 5.14, the geosphere is divided into four layers: the **crust**, **mantle**, **outer core** and **inner core** (Figure 17.1.2). The layers differ in composition and whether they are solid or liquid. With increasing depth, the temperature and pressure in Earth increases. The mantle's temperature ranges from 200°C to 4000°C. The temperature of the inner core is similar to the surface temperature of the Sun – about 5400°C.



▲ FIGURE 17.1.2 The layered structure of Earth

crust

the outermost and thinnest layer of Earth

mantle

the rock layer between the crust and the core of Earth

outer core

the liquid part of Earth's metallic core

inner core

the innermost solid, metal part of Earth

The crust is the outermost and thinnest layer of Earth. It consists of oceanic and continental crust. Oceanic crust lies under the oceans and is less than 10 kilometres thick. It is mainly composed of the igneous rocks basalt and gabbro. The continental crust is thicker than oceanic crust and forms the continents and nearby shallow oceans. Continental crust is composed of a variety of rocks and is much older and less dense than oceanic crust.

The mantle lies between the crust and the core. It makes up two-thirds of mass of the solid part of Earth and 84 per cent of the volume of Earth. The mantle is composed of iron-rich rock and is solid but moves very slowly over time. Over millions of years, mantle flow carries heat between the core and the crust.

The core of Earth is composed of the metals iron and nickel. It is divided into the outer and inner core. The outer core is liquid and the inner core is solid. This difference is caused by enormous pressure deep in Earth that stops metal melting in the inner core. Earth's magnetic field is created by movement of liquid materials in the outer core.

17.1 LEARNING CHECK

- 1 **List** the layers of Earth and **state** whether each is liquid, gaseous or solid.
- 2 **Identify** the thickest layer of the solid Earth.
- 3 **Construct** a table of the layers of the geosphere including the layer name, what it is made of and its thickness. You may need to do some extra research.
- 4 **Contrast** ocean and continental crust, identifying as many differences as possible.
- 5 **Draw** a labelled diagram of the structure of Earth.

17.2 Plate tectonics

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ state the theory of plate tectonics
- ✓ describe the processes that cause Earth's plates to move.

GET THINKING

Look closely at the illustrations in this module. What do you think they are trying to show?

lithosphere

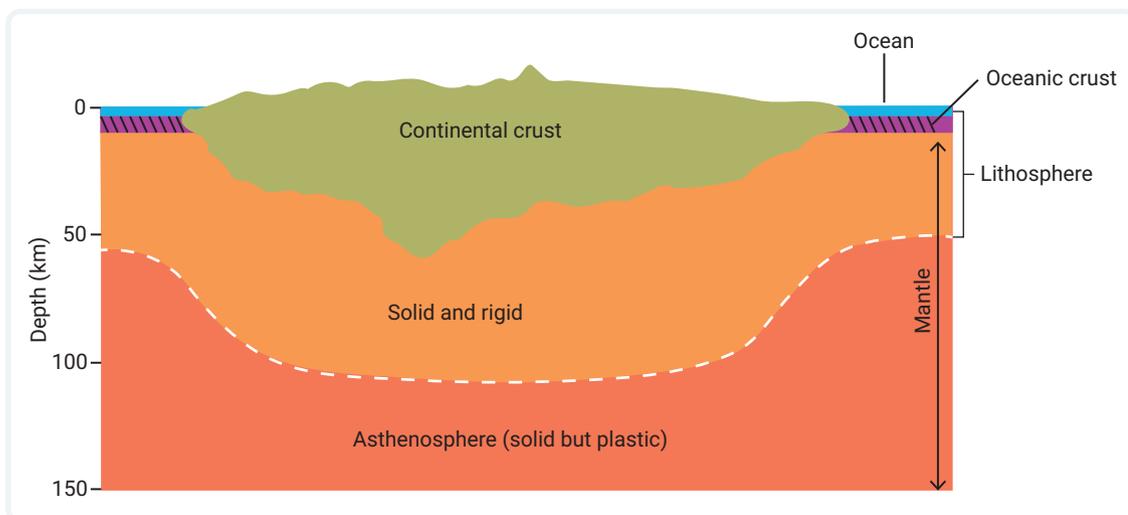
Earth's crust and the rock-like upper part of the mantle

asthenosphere

the solid part of the mantle below the lithosphere (which can flow)

The theory of plate tectonics

Two important components of the geosphere are the **lithosphere** and **asthenosphere** (Figure 17.2.1). The lithosphere is made up of Earth's crust and the brittle, rock-like part of the mantle underneath it. Forces can cause the lithosphere to change shape or fracture. The lithosphere is thickest under continents and thinnest under oceans.



▲ FIGURE 17.2.1 Differences in the thickness of continental and oceanic lithosphere

The plate tectonics theory states that Earth's lithosphere comprises pieces called plates that move relative to each other. The movement of the plates causes the major topographic features of Earth: mountains (on land and under the ocean), ocean basins and deep-sea trenches. The word 'tectonic' comes from the Greek word *teuton*, meaning 'builder'.

Beneath the lithosphere is the asthenosphere. Although still part of the solid mantle, the asthenosphere is much hotter and more fluid than the lithosphere. On average, the asthenosphere is 180 kilometres thick. Heat from deep within Earth keeps the asthenosphere plastic so it can flow (like toothpaste) and allows the lithosphere to move. As forces act on a plate, the asthenosphere allows the plate to move horizontally and to rise or sink. When erosion removes rock from a mountain, the mountain slowly rises as the weight is removed. It is like a canoe rising in the water when someone gets out.

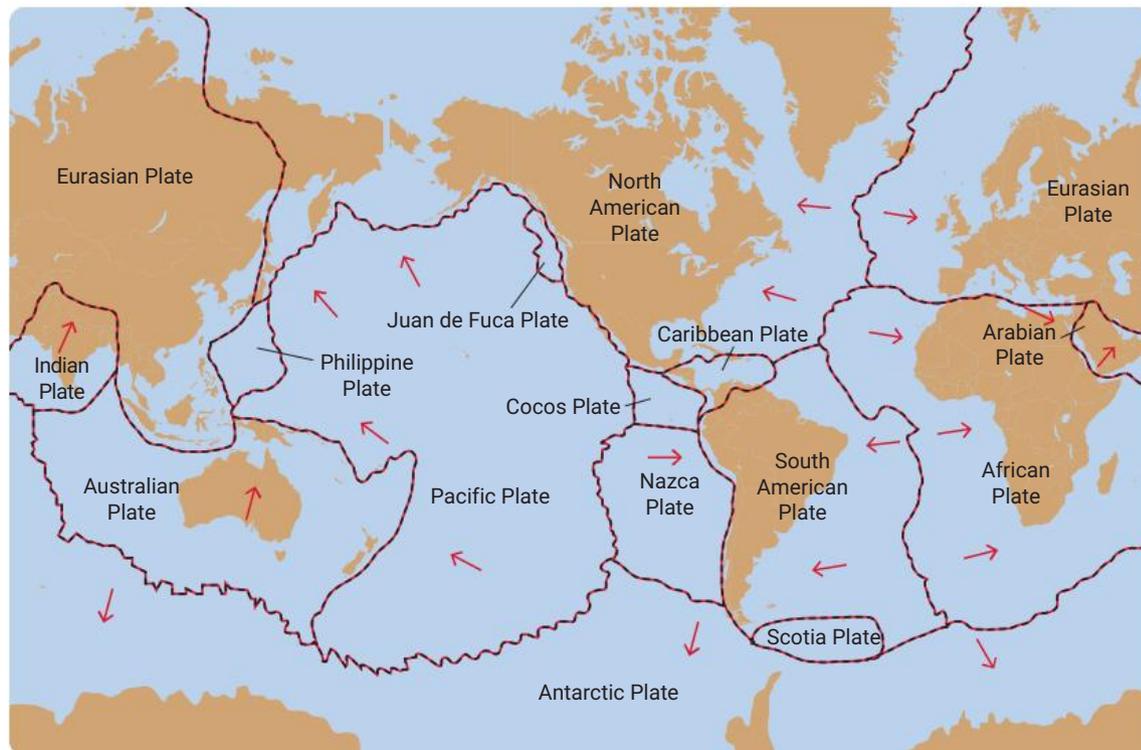


Video activity
Plate tectonics

Interactive resource
Drag and drop:
Convection currents
and slab pull

The plates of Earth

Figure 17.2.2 shows the major and minor plates of Earth. The arrows show the direction in which each of the plates is moving. Notice how some plates are moving away from each other and others are moving towards each other.



▲ FIGURE 17.2.2 The plates of Earth. The arrows indicate the direction the plates are moving.

There are two types of plate. An **oceanic plate** is a lithospheric plate that contains mainly oceanic crust. The Pacific Plate and the Nazca Plate are composed only of oceanic crust. A **continental plate** is a lithospheric plate containing a lot of continental crust. The Australian Plate, the African Plate and the Eurasian Plate are all continental plates, although they also contain some oceanic crust.

Plates move at speeds ranging from less than 2 to about 20 metres per hundred years. The average rate is about 10 centimetres per year, with oceanic plates moving faster than continental plates.

Continental and oceanic crusts have different structures. Table 17.2.1 summarises the differences between continental and oceanic crust.

▼ TABLE 17.2.1 The features of oceanic and continental plates

Feature	Oceanic plate	Continental plate
Average thickness (km)	7	35
Average density (g/cm^3)	3.0	2.7
Composition	Thin sediment layer over rocks with a composition like basalt	Wide range of rock types; composition similar to granite
Structure	Layered	Sedimentary layers and folded and forced rocks

oceanic plate
a lithospheric tectonic plate that contains mainly oceanic crust

continental plate
a lithospheric tectonic plate containing a lot of continental crust

Why plates move

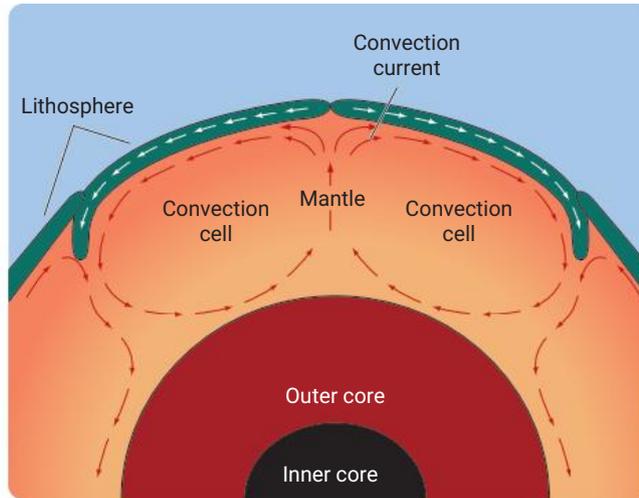
ridge push

the process that moves crust away from a mid-ocean ridge

slab pull

the force driving tectonic plate motion caused by a sinking plate

There are two main causes of plate motion: **ridge push** and **slab pull**. Convection, the process that transfers heat in a fluid and is caused by temperature differences, provides the energy for plate motion. At the surface, gravity causes old, cold ocean lithosphere to sink down into the mantle (Figure 17.2.3).

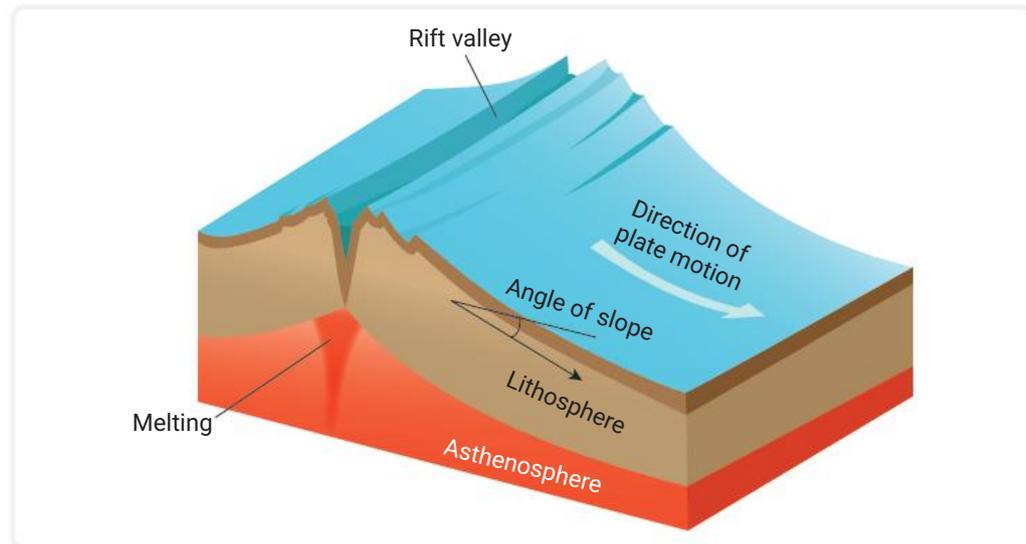


▲ FIGURE 17.2.3 Convection and plate motion are related.

mid-ocean ridge

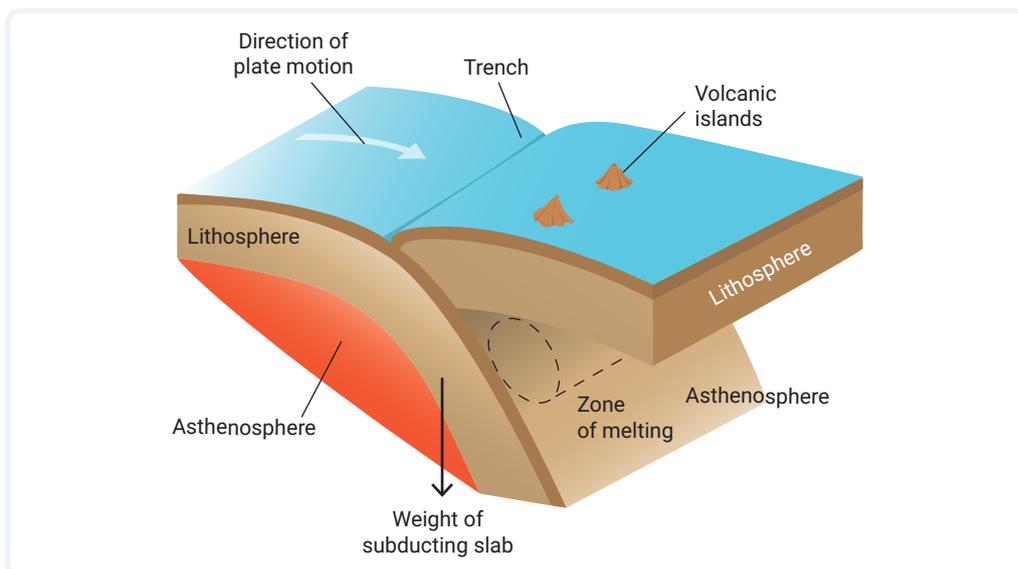
a broad, high, underwater mountain range in the ocean at a divergent plate boundary

Ridge push explains why plates move away from a **mid-ocean ridge**. Because the centre of the ridge is several kilometres above the deeper ocean floor, the lithosphere slowly slides down due to gravity. As it slides, the plate near the ridge pushes other parts of the plate ahead of it (Figure 17.2.4).



► FIGURE 17.2.4 Ridge push: lithosphere slides down the slope away from the boundary

Slab pull is caused by a sinking, or subducting, plate. It is the major cause of plate motion. When the ocean lithosphere begins to sink, it pulls the rest of the plate behind it. The plate it sinks beneath pushes up against the subducting plate and prevents the subducting plate from accelerating (Figure 17.2.5). You will learn more about how plates interact, as well as more detail about some of these terms, in the following modules.



◀ **FIGURE 17.2.5**
Slab pull: the weight of the subducting slab pulls the plate towards the trenches

Convection from a cold surface

☆ ACTIVITY

Materials and equipment

- water
- 250 mL beaker
- ice cube
- food colouring

Procedure

- 1 Add 200 mL of water to the 250 mL beaker. Wait until the water is still.
- 2 Carefully float the ice cube in the centre of the beaker of water.
- 3 Add three drops of food colouring to the water at the beaker's edge. Record what the dyed water does.
- 4 Carefully add three drops of food colouring to the top of the ice cube. Observe and record what happens when the food colouring enters the water.

Analysis

- 1 What happens to the cooling water below the ice cube?
- 2 How does the movement of the food colouring support the idea of a descending body of cold fluid?
- 3 Why is this an example of convection?

17.2 LEARNING CHECK

- 1 What is a lithospheric plate?
- 2 How is a continental plate different from an oceanic plate?
- 3 **State** the theory of plate tectonics.
- 4 What does the theory of plate tectonics explain?
- 5 **Explain** ridge push.
- 6 **Explain** slab pull.
- 7 **Explain** how both ridge push and slab pull contribute to convection in the mantle.
- 8 Search the internet for a copy of a blank tectonic plates map and **label** the plates.

17.3 Plate boundaries

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

✓ describe features of convergent, divergent and transform boundaries.



Interactive resource
Label: Features of plate boundaries

Match: Types of boundaries

GET THINKING

If plates move in different directions, what happens at their edges? What happens when they run into each other? Are gaps created when they move apart?

How plates interact

There are three types of plate boundaries (Figure 17.3.1). They are:

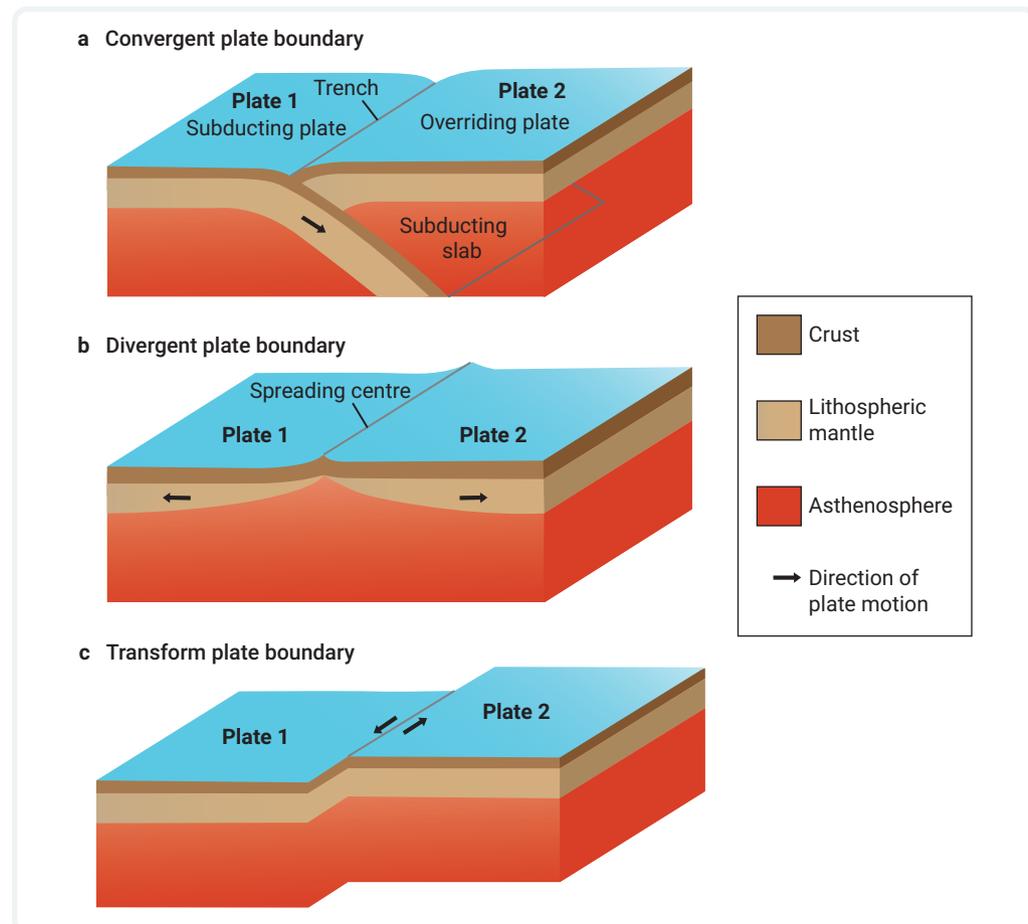
- **convergent boundaries** – crust is destroyed as one plate is pushed underneath another as they approach each other (a process called **subduction**), or two continental plates collide
- **divergent boundaries** – new crust is generated as the plates move away from each other
- **transform boundaries** – the plates slide horizontally past each other.

convergent boundary
the border at which crust is destroyed as one plate moves beneath another, or where two continental plates collide

subduction
the process in which one oceanic plate sinks beneath another plate at a convergent boundary

divergent boundary
the border at which new crust is formed as tectonic plates pull away from each other

transform boundary
the border between two tectonic plates that are sliding past each other



▲ FIGURE 17.3.1 Three types of plate boundaries: (a) convergent, (b) divergent and (c) transform. Notice that a convergent boundary demonstrates slab pull (Figure 17.2.5) and a divergent boundary demonstrates ridge push (Figure 17.2.4).

As the plates move, they create distinctive structures that help to identify the processes that are happening at the plate boundary (Table 17.3.1).

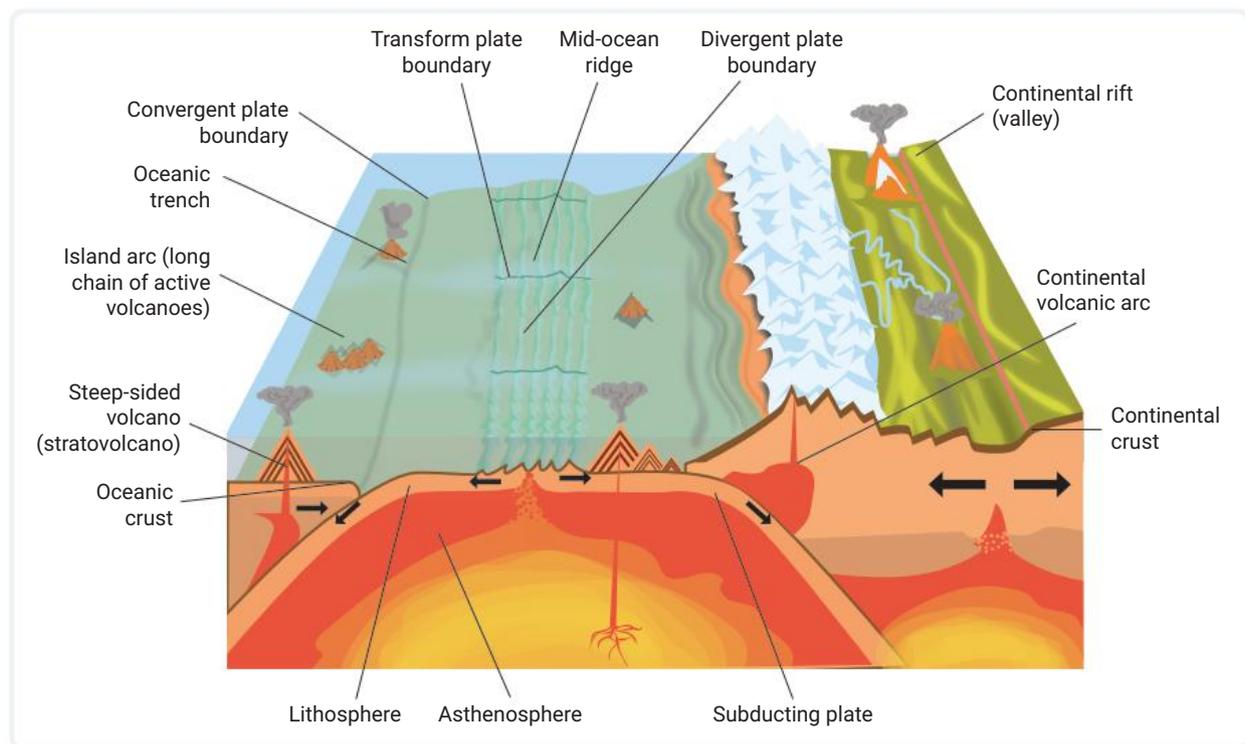
▼ TABLE 17.3.1 Plate boundaries and their characteristics

Boundary type	Types of plates involved	Structures created	Volcanic activity	Earthquake activity
Divergent	Oceanic–oceanic	<ul style="list-style-type: none"> • Mid-ocean ridges and central rift valleys • Faults 	Basaltic lavas from vents in the seafloor	Shallow (0–70 km)
	Continental–continental	<ul style="list-style-type: none"> • Rift valleys • Faults 	Volcanoes form along edges of rift	Shallow (0–70 km)
Convergent	Oceanic–oceanic	<ul style="list-style-type: none"> • Trench • Chain of volcanic islands • Faults 	Volcanoes that erupt in an explosive way, generating large amounts of ash	Shallow to deep (0–700 km)
	Continental–oceanic	<ul style="list-style-type: none"> • Trench • Mountain belt with volcanoes • Faults 		Shallow to deep (0–700 km)
	Continental–continental	<ul style="list-style-type: none"> • Fold mountains • Faults 	None	Shallow to intermediate (0–300 km)
Transform	Continental–continental or Oceanic–oceanic	<ul style="list-style-type: none"> • Faults 	None	Shallow (0–70 km)

fault

a fracture on Earth's surface where rocks have moved due to tension or compression forces

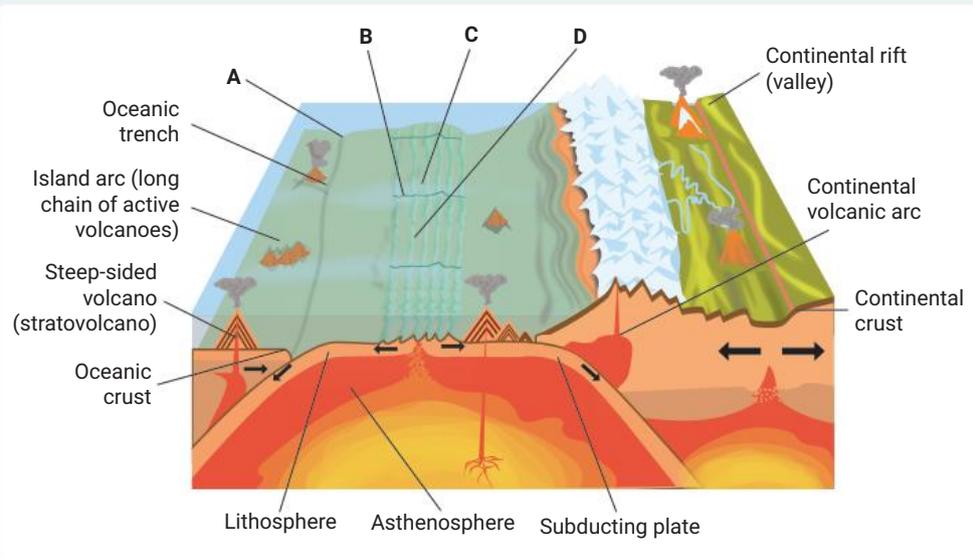
Some of the structures described in Table 17.3.1 are shown in Figure 17.3.2.



▲ FIGURE 17.3.2 Features of different plate boundaries

17.3 LEARNING CHECK

- 1 **Describe** what occurs at a:
 - a convergent boundary.
 - b divergent boundary.
 - c transform boundary.
- 2 What geographical features occur at divergent and convergent boundaries? **Explain** the processes involved in formation of these features.
- 3 Look at this diagram and then answer the questions below.



- a Where is the oldest seafloor located: A, B, C, or D?
 - b At which locations would shallow earthquakes occur?
 - c The features at C and D are related to each other. Describe the feature at C and the type of boundary found there.
- 4 Earth's oceans contain all three types of plate boundaries. **Construct** a table to summarise the volcanic activity and earthquake activity found at divergent, convergent and transform boundaries in oceans.
 - 5 **Explain** why 'destructive boundary' is another name for a convergent boundary.



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ extracting information from direct observations
- ▶ processing and representing data.



Safety

Use tongs and take care when handling hot items. Don't eat the food used in the investigation.

CHEESY PLATE TECTONICS

AIM

To model the layers of Earth and demonstrate the movement of tectonic plates

MATERIALS AND EQUIPMENT

- 2 tortilla wraps
- 2 slices of cheese
- large piece of aluminium foil
- hot plate
- metal tray
- tongs
- heatproof mat or ceramic tile

PROCEDURE

- 1 Place the aluminium foil onto the metal tray.
- 2 Place two slices of cheese on the piece of aluminium foil, approximately half a tortilla wrap's distance apart.
- 3 Place a tortilla wrap on top of each of the slices of cheese, ensuring the edges of the tortillas are just touching.
- 4 Place the metal tray onto the hot plate and begin to slowly heat it.
- 5 Heat until the cheese is completely melted, then use the tongs to remove the metal tray from the hot plate and place it on a heatproof mat or ceramic tile.

- 6 Using the tongs in one hand to keep the tray steady (and being careful not to touch the tray), place the other hand on top of one of the tortilla wraps and attempt to slide it sideways into/on top of the other tortilla wrap. Take note of what happens and record the results.
- 7 Now place one hand on top of each of the tortillas. Slide them slowly apart as far away as possible from each other. Take note of what happens to the cheese and record the results.

RESULTS

Copy and complete a table like the one below.

Activity	Observation
Sliding one tortilla into the other	
Sliding tortillas apart	

- 1 Which layers of Earth do you think the tortilla and the cheese represent, respectively?
- 2 What does sliding one tortilla into the other represent on Earth?
- 3 Where on Earth does this kind of event occur?
- 4 What happened to the cheese when you slid the tortillas away from each other? What do you think this represents on Earth?

CONCLUSION

Write a conclusion about how your tectonic plate experiment relates to real-life phenomena that occur on Earth. Use your observations to support your arguments.

17.5 Evidence for plate tectonics

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ outline the evidence supporting the theory of plate tectonics.



Quiz
Evidence for plate tectonics

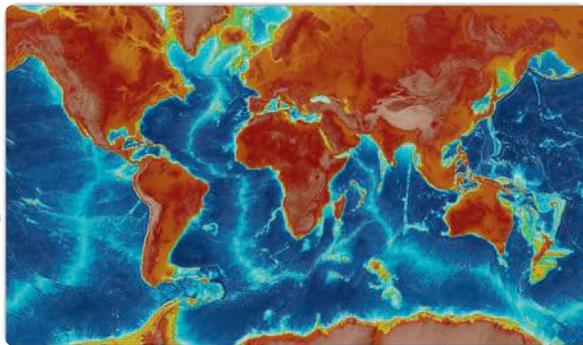
GET THINKING

How can you convince someone to understand something they cannot see? Scientists had to convince other scientists that plates and their interactions were the cause of the features of Earth. Look at the headings in this module and make a list of your ideas of what type of evidence would support the plate tectonics model.

The theory of plate tectonics was developed during the 1960s. It was built on the idea of continental drift put forward by Alfred Wegener in the early 20th century, which you will learn about in Module 17.7. Over time, new technologies have allowed scientists to collect more evidence in support of the theory of plate tectonics.

The shape of the ocean floor

The ocean floor was once thought to be flat and unchanging. In the 1940s, scientists began to use sonar to study the ocean floor. Sonar uses reflected sound waves to measure the depth of the seafloor and build up a picture of its topography. Scientists found a broad, high mountain range that extended 65 000 kilometres around the world in the deep ocean – a mid-ocean ridge (Figure 17.5.1). Fossils from deep sea drilling and magnetic information revealed that the seafloor was youngest at the mid-ocean ridge and progressively older the further away they were from the ridge. The oldest rocks in the ocean are less than 180 million years old. This was evidence that the seafloor was indeed changeable and that ocean basins grow over time.



▲ FIGURE 17.5.1 Earth's topography. The light areas in the centre of oceans are the peaks of mid-ocean ridges.

Magnetic striping of seafloor basalts

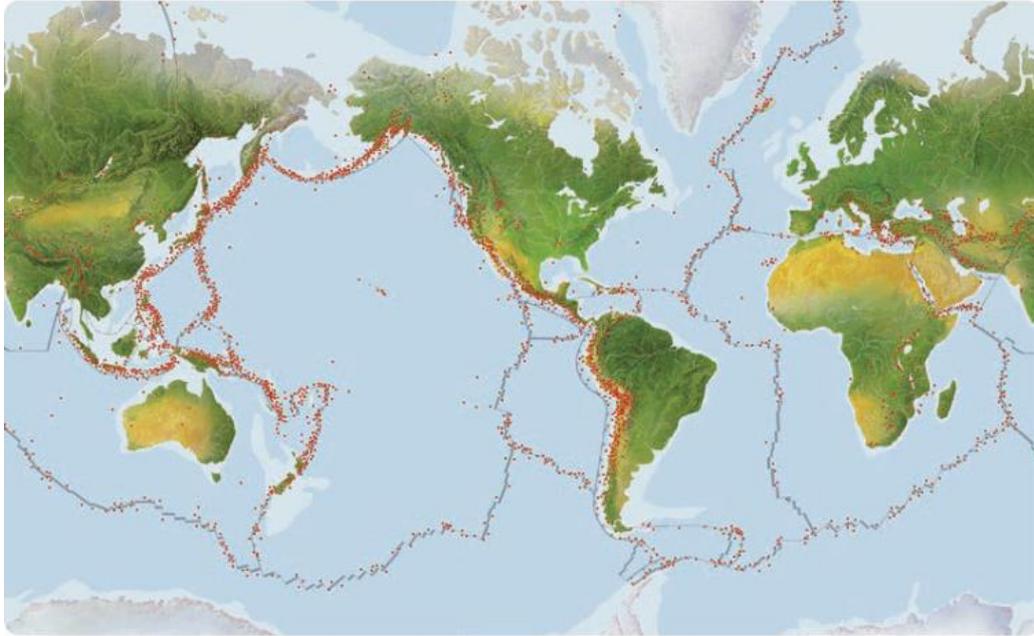
In the 1950s and 1960s, marine scientists created maps of the seafloor magnetism. The maps showed a distinctive striped pattern parallel to the mid-ocean ridge. You will learn more about this in Module 17.8. The scientists also detected transform faults – evidence that parts of the seafloor moved relative to each other.

Earthquake distribution

Earthquakes occur where enormous forces fracture and move rocks. Scientists found that large earthquakes did not occur randomly, but were sited along mid-ocean ridges and parallel to deep ocean trenches. Earthquake activity on Earth tends to follow the edges of the tectonic plates, where the plates interact with each other (Figure 17.5.2).

earthquake

a violent shaking of the ground caused by energy-carrying waves

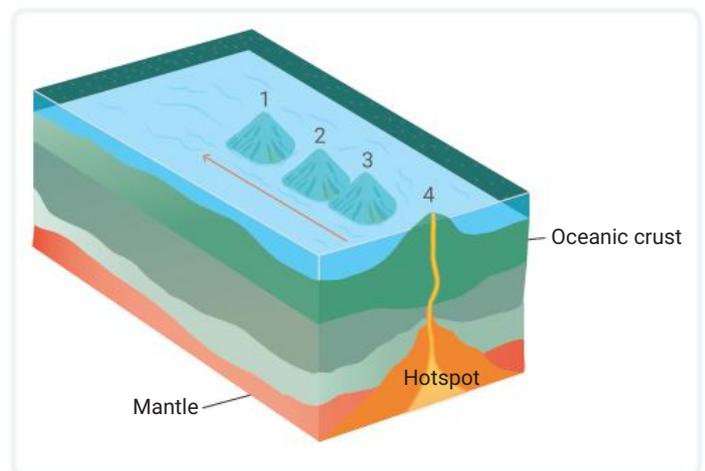


Science Photo Library / Alamy Stock Photo

▲ FIGURE 17.5.2 Distribution of earthquakes and volcanoes on Earth

Ages of hotspot volcanoes

In the ocean, there are linear chains of volcanic islands. Scientists have discovered they are ordered in age and created by a moving plate. The volcanoes are built from magma produced by a **hotspot** in the mantle. As the plate moves the volcano away from the hotspot, the volcano stops being active and a new one begins to form over the hotspot (Figure 17.5.3).



▲ FIGURE 17.5.3 How hotspot volcanoes form. The moving plate carries volcanoes away from where they first form. Volcano 1 is the oldest. Volcano 4 is the newest.

17.5 LEARNING CHECK

- 1 **List** four types of evidence supporting the plate tectonic theory.
- 2 How did evidence from the seafloor support the idea that the ocean floor changed through time?
- 3 **a Describe** where earthquakes and volcanoes occur on Earth.
b Earth's earthquakes and volcanoes are not distributed randomly over Earth's surface. Where does plate tectonics predict earthquakes and volcanoes will occur?
- 4 **Explain** how the direction of ageing of oceanic volcanoes relates to the movement of the plate they are on.

hotspot

an unusually hot area in Earth's upper mantle where the mantle melts



Using maps to present scientific data

SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ summarising and presenting scientific data in maps.

Maps are a great way to organise and process large amounts of data. Maps present information as a picture rather than a series of numbers.

- ▶ **Five characteristics of a good map are:**
 - title – make your title descriptive, so that the purpose of your map is clear
 - scale – indicate a scale so the reader knows the distances represented on the map
 - legend – a legend is a key to symbols on a map. A key is a list of symbols and names of what the symbols represent. Use clear, simple symbols and choose colours that can easily be distinguished from each other
 - compass – a compass shows which way is north, so that a reader can orient the map easily
 - lines of latitude and longitude – these lines can help a reader work out where on Earth your map is located.



Video

Science skills in a minute: Presenting data in different forms

Science skills resource

Science skills in practice: Data in different forms

USING MAPS TO SUMMARISE INFORMATION AND SHOW PATTERNS

AIM

To create a map showing the location of convergent boundaries in the Pacific and East Asia

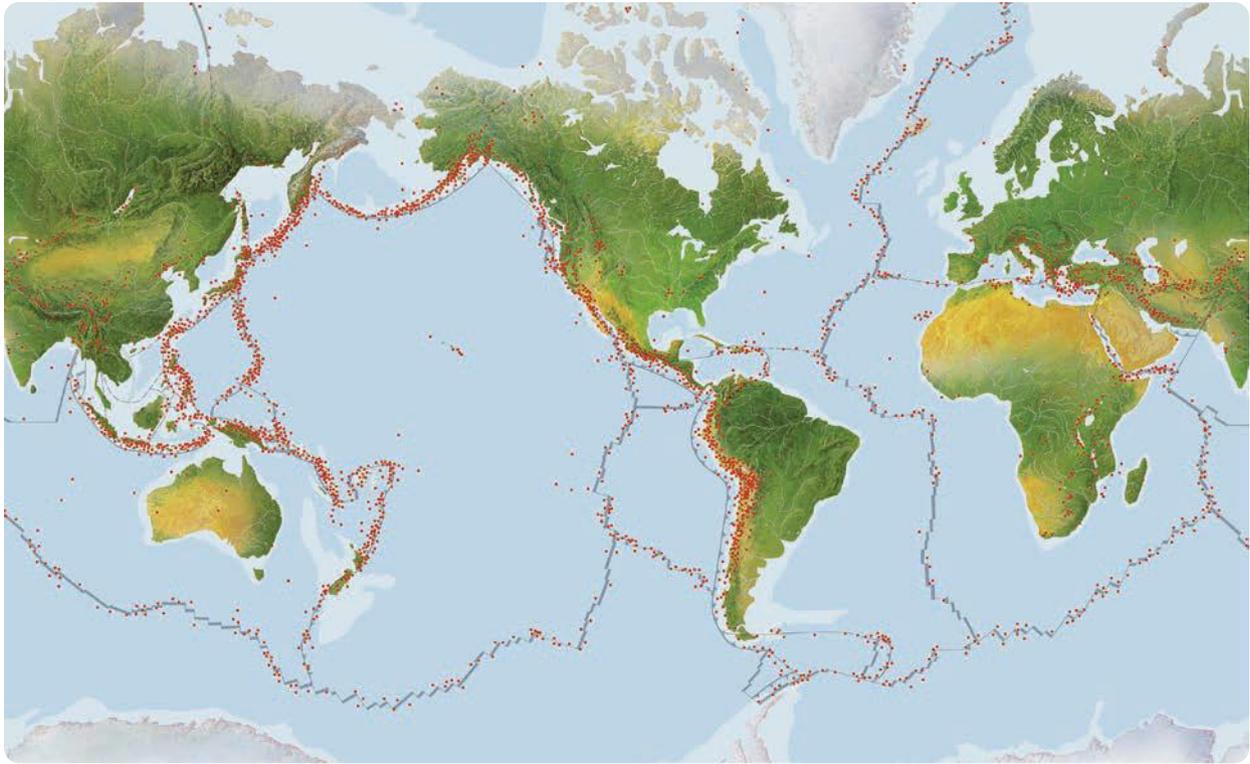
MATERIALS AND EQUIPMENT

- a world map with tectonic boundaries marked on it, covering the Pacific and East Asia
- coloured pencils

PROCEDURE

Convergent boundaries involving oceanic crust have:

- trenches
 - fold mountains
 - zones of shallow to deep earthquakes
 - stratovolcanoes erupting ash.
- 1 On the world map, identify and mark with a blue pencil the location of ocean trenches.
 - 2 Create a key in the bottom centre of the map. Add a blue line and the word 'Trenches' to your key.
 - 3 Study the earthquake distribution in the map in Figure 17.6.1. Remember that convergent boundaries are marked by wide zones of descending (shallow to deep) points where earthquakes have occurred. Use at least one other information source to check where such zones of shallow to deep earthquakes occur.
 - 4 Use a different coloured pencil and shade in zones of descending earthquakes. Add your shading and a name to the key.
 - 5 Search the internet for the National Centers for Environmental Information Natural Hazards Viewer to locate volcanoes around the Pacific, in the Philippines and in Indonesia.
 - 6 Use a new pencil colour and mark on your map the zones where the volcanoes are found. Do not try to add every volcano. Add your symbol to the key.



Science Photo Library/Gary Hincks/Alamy Stock Photo

▲ FIGURE 17.6.1 Distribution of earthquakes and volcanoes

- 7 Use Figure 17.2.2 to add arrows on your map showing the direction of movement for the Australian, Nazca and Pacific plates.
- 8 Add a title to your map.

ANALYSIS

- 1 How closely related are the earthquakes, volcanoes and trenches?
- 2 Do the directions of plate motion match the location of the convergent boundaries?
- 3 Why is a key important in making your map understandable?
- 4 Explain why a map like this is more useful than a table of data.

17.7 Continental drift

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

✓ outline the theory of continental drift and the evidence supporting it.

supercontinent

a continent composed of all or most of Earth's continents

Pangaea

a supercontinent that once existed on Earth; the name means 'all lands'

continental drift

the movement of the continents across the surface of Earth over geological time

GET THINKING

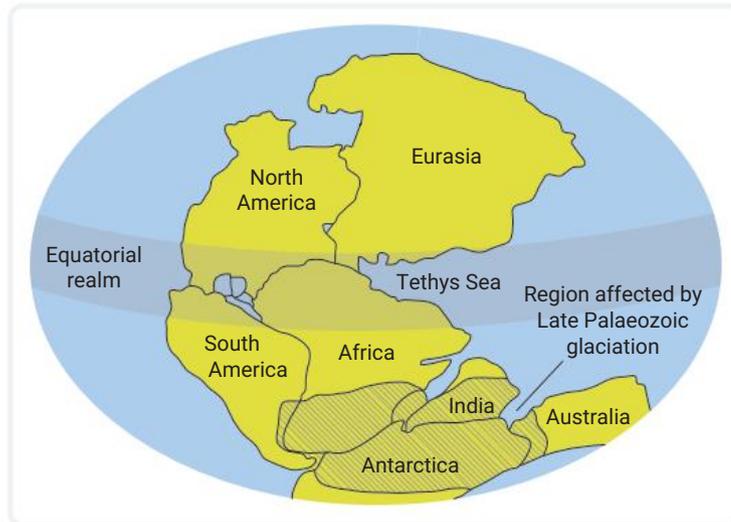
How could all of the continents that exist today have originally been one giant continent? What evidence supports this idea?

Alfred Wegener and Pangaea

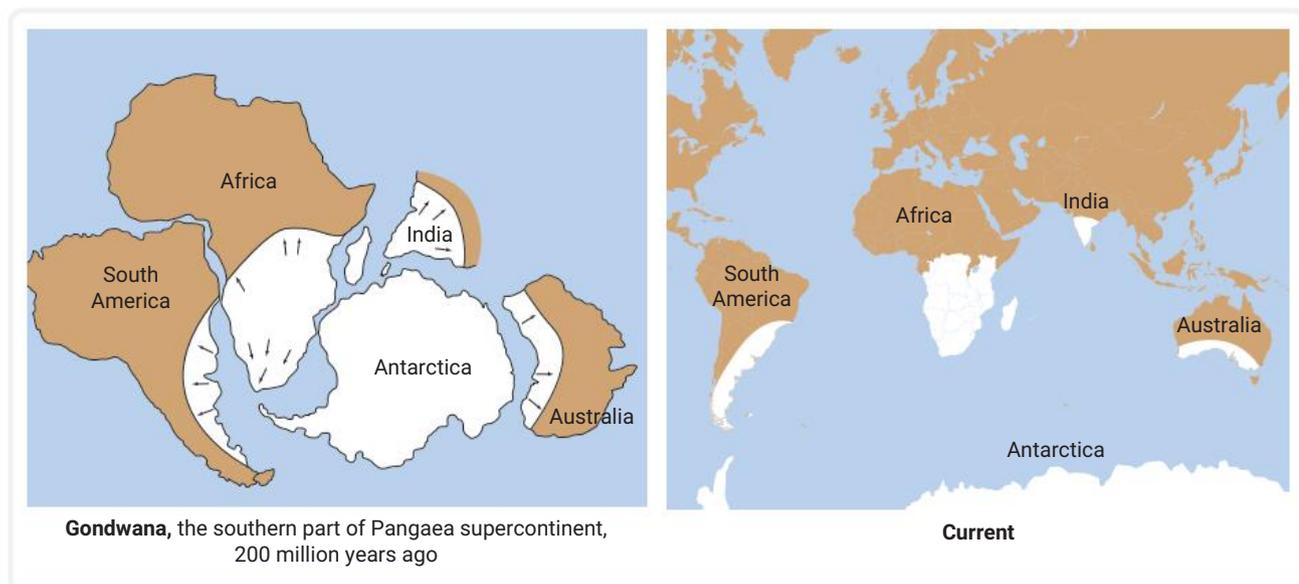
In 1912, a German scientist called Alfred Wegener proposed that in the past all the continents on Earth had been joined together as part of a **supercontinent**. Wegener named the supercontinent **Pangaea** (Figure 17.7.1).

Wegener was a meteorologist and developed his theory by studying past climates, through evidence preserved in rocks. He wondered why, 200 million years ago, there were tropical forests in the northern hemisphere, with ice sheets in the southern hemisphere at a similar distance from the equator (Figure 17.7.2).

Wegener proposed that continents could move. He found that the existence of a supercontinent could account for cold areas near the South Pole and the tropical forests near the equator. This is what we see today. Wegener's theory is known as **continental drift**.



▲ FIGURE 17.7.1 The supercontinent Pangaea



▲ FIGURE 17.7.2 Glacial deposits in Pangaea, and where evidence of past glacial deposits is found now. Arrows show direction of ice movement.

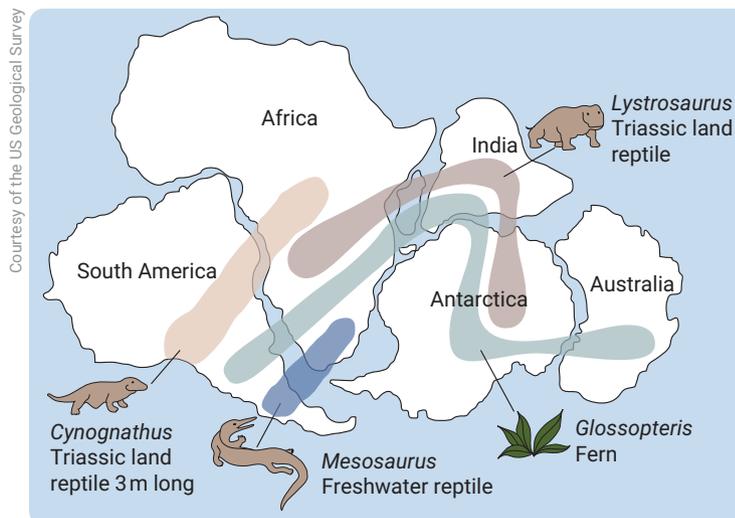
Evidence for continental drift

Wegener assembled a lot of evidence to support his theory, including:

- the shape of continents – the coastlines of adjacent continents seem to fit together. This is best seen with the coasts of Africa and South America (Figure 17.7.2)
- rocks reflecting different climates – their distribution makes sense if they are part of a supercontinent that extended from the South Pole past the equator (Figure 17.7.3)
- fossils – animal and plant fossils would form continuous distributions across a supercontinent. It would have been difficult for land animals to travel across oceans if the continents had been separated (Figures 17.7.4 and 17.7.5)
- the continuation of geology across matching coastlines – mountain belts and old, stable parts of the continent appear to continue across coast lines at the points where continents would previously have been joined.



▲ **FIGURE 17.7.3** Rock that has been polished and scratched by a glacier at Inman Valley in South Australia. This is evidence of a past glacial deposit.



▲ **FIGURE 17.7.4** Fossil evidence explained by continental drift. The four coloured areas show the distributions of the named species.



Universal Images Group North America LLC / Alamy Stock Photo

▲ **FIGURE 17.7.5** *Cynognathus* was a mammal-like reptile that lived on Pangaea 251–246 million years ago. Today its fossils are found in South America and Africa.

Continental drift and convection

In Wegener's time, many scientists believed that the oceans and continents were fixed rigidly in place, and they disagreed with Wegener's theory. The biggest problem facing the idea of continental drift was that no one knew what could move a continent. A British scientist, Arthur Holmes, proposed that convection could move continents. Finally, in the 1960s, scientists discovered how ocean crust grows and is destroyed. (We will see how in Module 17.8.)



Video activity
The scientist behind the plate tectonics theory

17.7 LEARNING CHECK

- 1 **State** the theory of continental drift.
- 2 What was the name of the supercontinent proposed by Alfred Wegener?
- 3 **List** four types of evidence used to support the theory of continental drift.
- 4 What could Wegener's theory not explain about continental drift?
- 5 **Explain** how the fossil distribution of *Mesosaurus* (refer to Figure 17.7.4) supports the theory of continental drift.

17.8 Seafloor spreading

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe the process of, and evidence for, seafloor spreading
- ✓ explain changes in the age of the ocean floor using seafloor spreading.



Quiz
Seafloor magnetic patterns

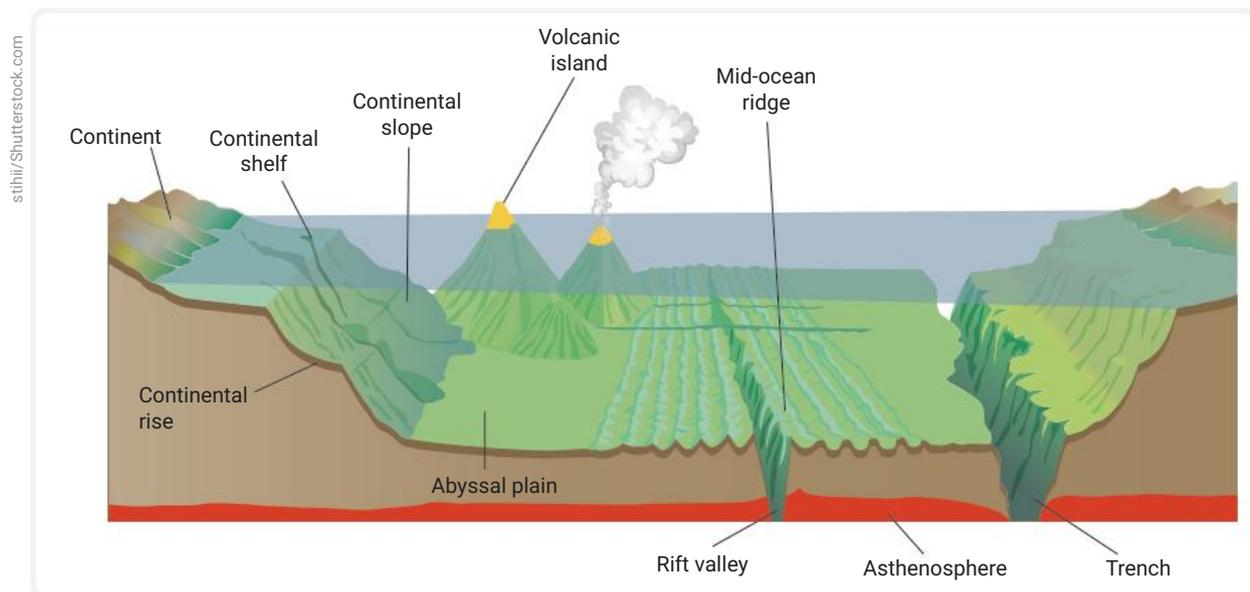
Interactive resource
Label: Features of the seafloor

GET THINKING

What is seafloor spreading? Why was its discovery an important contribution to the theory of plate tectonics?

Seafloor spreading

Until the 1950s, very little was known about the ocean floor. When US geologists Marie Tharp and Bruce Heezen published the first detailed maps of the seafloor, they showed undersea mountains rising above a flat abyssal plain and an underwater mountain range. This range, called a mid-ocean ridge (see Modules 17.2 and 17.3), runs the length of the Atlantic Ocean. The maps were based on echo soundings made by ships sailing across the Atlantic Ocean. Echo sounding is used to produce images of the seafloor by bouncing sounds off the seabed and working out how far the sound travels. As scientists discovered new features of the ocean floor (Figure 17.8.1), they developed theories to explain what they found.

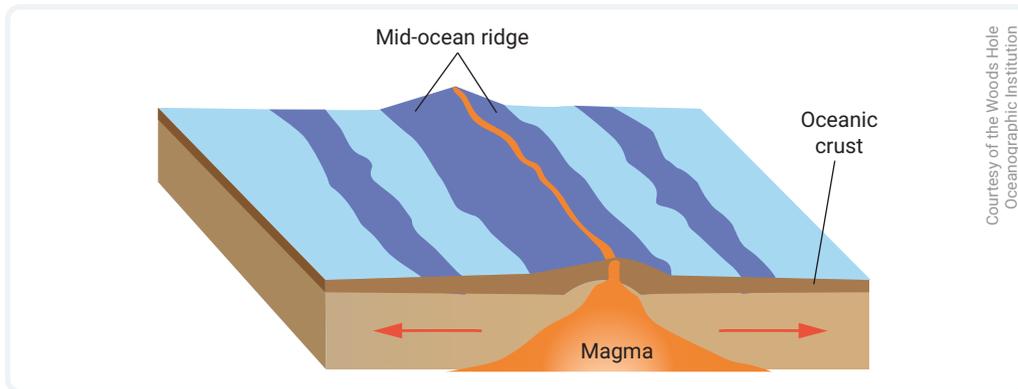


▲ FIGURE 17.8.1 Features of the seafloor

seafloor spreading

the theory that new seafloor is created at mid-ocean ridges, spreads outwards and then descends into the mantle at trenches

In 1960, US researchers Robert Dietz and Harry Hess proposed a theory called **seafloor spreading**. They suggested that new seafloor is created at mid-ocean ridges, spreads outwards and then descends into the mantle at trenches. As the plates move apart over the asthenosphere, magma rises at the centre of the mid-ocean ridge and solidifies, creating new seafloor. This process continues to form more and more new seafloor. (Figure 17.8.2).



▲ FIGURE 17.8.2 A mid-ocean ridge where new crust is formed. The stripes record changes in Earth's magnetic field (see Figure 17.8.4).

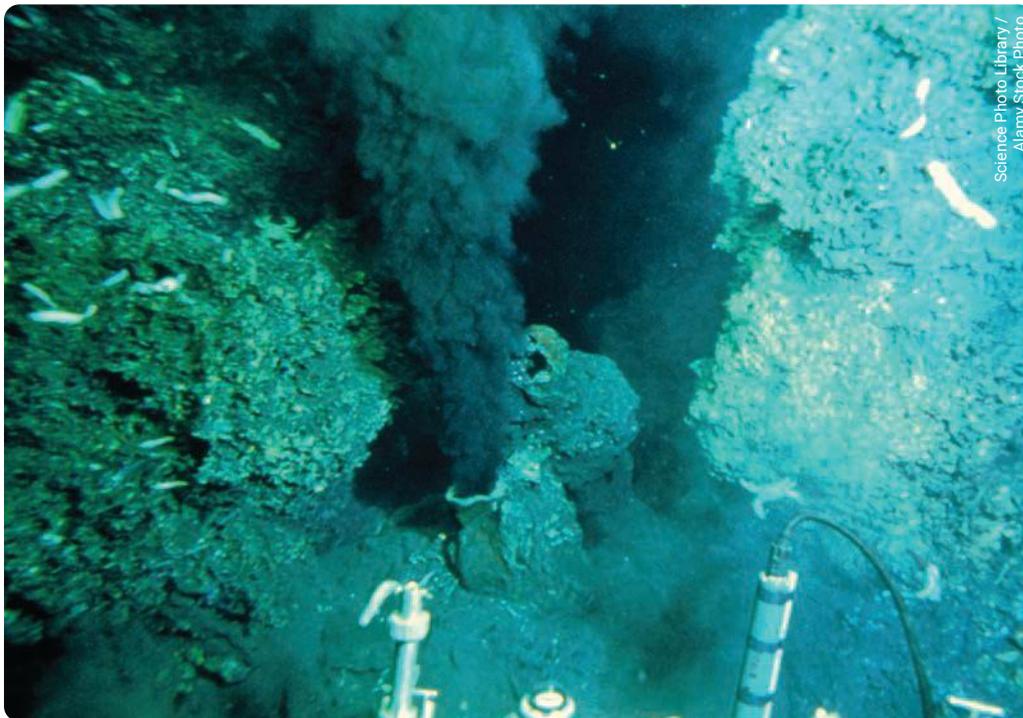
Evidence for seafloor spreading

Scientists soon found supporting evidence for seafloor spreading.

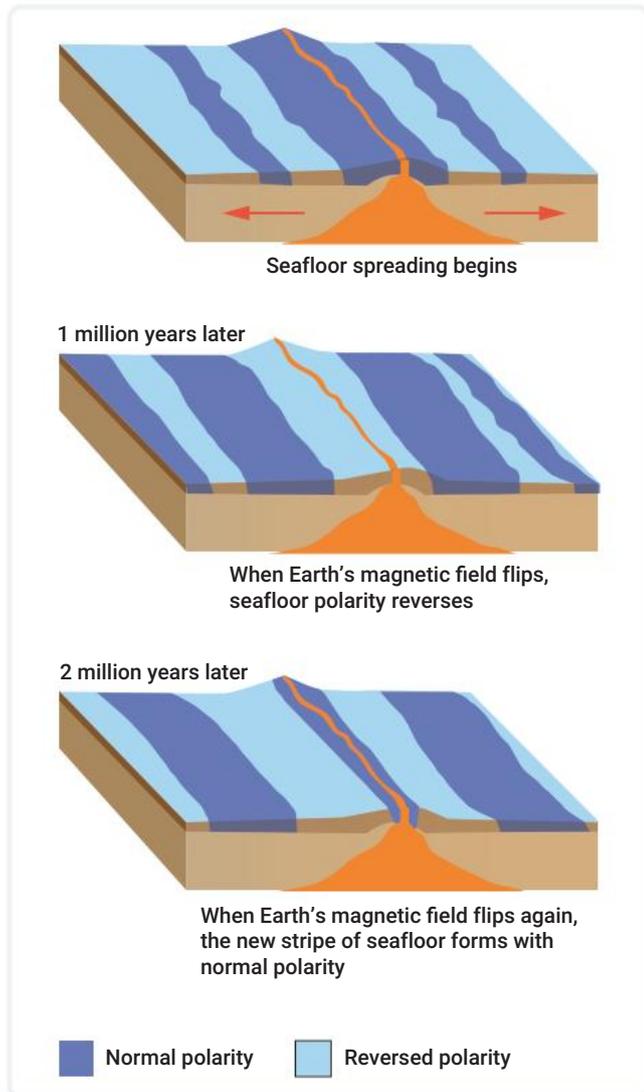
Heat flow and gravity

Surveys from ships across mid-ocean ridges noted that heat flow from the seafloor increased over the centre of the ridge. The central valley is a **rift**, created by the rocks being pulled apart. The increase in heat flow suggested that hot magma was close to the top of the mid-ocean ridge. Today we know that within the central valley of a mid-ocean ridge, basalt lava is squeezed onto the seafloor and hot water escapes from cracks in the crust called hydrothermal vents (Figure 17.8.3).

rift
a valley created by rocks being pulled apart



▲ FIGURE 17.8.3 A hydrothermal vent



▲ FIGURE 17.8.4 How magnetic seafloor ‘stripes’ are created

Magnetic patterns in ocean floor rocks

Just as magnetic patterns serve as evidence for the theory of plate tectonics (see Module 17.5), they also serve as evidence for seafloor spreading. Measurements of the magnetism of the seafloor show linear patterns parallel to and symmetrical about the mid-ocean ridge. The stripes reflect new seafloor being made, and continuously moving away from the ridge (Figure 17.8.4).

When a basalt lava or magma cools, magnetic minerals line up with Earth’s magnetic field, and this shows the direction of the magnetic field. As the rock crystallises, the magnetite minerals preserve a record of the magnetic field at the time. The rock is then pushed outwards from the mid-ocean ridge and new seafloor is created.

Earth’s magnetic field changes direction randomly every 200 000–300 000 years. When scientists map the normal magnetism and the **magnetic reversal** on a map, the different areas appear as symmetrical stripes parallel to the ridge.

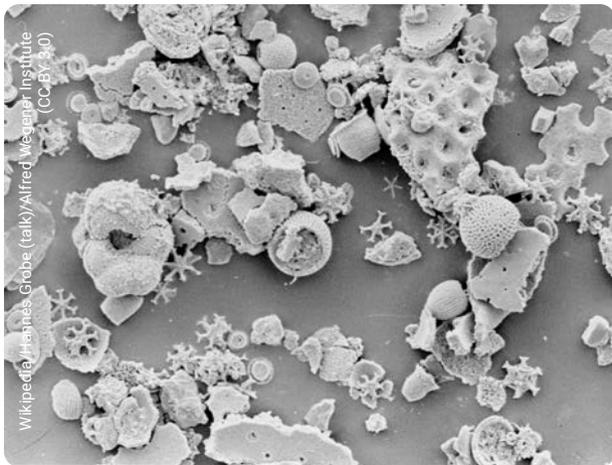
Studies of the magnetism and age of lava flows on land allowed scientists to date parts of the seafloor where magnetic reversals occur. They found that the age of the ocean floor increases as you move further away from the ridge.

Dating the seafloor

Magnetic reversals are not the only factor in studying the age of the seafloor. In the 1960s, a specially designed ship called the *Glomar Challenger* began drilling the seafloor (Figure 17.8.5). It drilled through sediments to the basaltic ocean crust below. The sediment contained fossil remains of single-celled organisms that once lived on the surface of the ocean (Figure 17.8.6). Because the ages of the fossils found directly above the basalt were known, they were used to determine the age of the ocean crust. The fossils confirmed that the rocks became older the further they were from the mid-ocean ridge.



▲ FIGURE 17.8.5 The *Glomar Challenger* drilled rock samples from the seafloor in the Atlantic Ocean, providing evidence that the seafloor became older the further away it was from the mid-ocean ridge.



◀ **FIGURE 17.8.6** Fossils from deep ocean sediments. Each of these shells is less than 0.1 mm wide.

DATA SCIENCE



Learn more about analysing cause-and-effect relationships in **Module 2.8**.

magnetic reversal

a change in the direction of Earth's magnetic field

Age of the seafloor

Table 17.8.1 shows the distance from the Mid-Atlantic Ridge and oldest fossil age from five drill sites as collected by the 1968 deep-sea drilling program by the *Glomar Challenger*.

▼ **TABLE 17.8.1** Some samples collected by the *Glomar Challenger*, 1968

Location	Distance from Mid-Atlantic Ridge centre (km)	Approximate fossil age (millions of years)
14	727	40
16	191	11
17	643	33
18	506	26
19	990	49

Procedure

- 1 Graph the age of the fossils against the distance from the Mid-Atlantic Ridge and draw a line of best fit through these points.
- 2 **Describe** the relationship between fossil age and distance from the Mid-Atlantic Ridge.

Analysis

- 1 How did this information support the theory of seafloor spreading?

☆ **ACTIVITY**

17.8 LEARNING CHECK

- 1 **Draw** a labelled diagram to describe a mid-ocean ridge.
- 2 **State** the theory of seafloor spreading.
- 3 **List** three pieces of evidence supporting the theory of seafloor spreading.
- 4 Why do maps of seafloor magnetism show stripes of normal magnetism and magnetic reversal?
- 5 How did deep-sea drilling of sediments support the theory that ocean floor varied in age?
- 6 **Explain** why ocean crust at the edge of an ocean is older than ocean crust formed at a mid-ocean ridge.



SCIENCE SKILLS IN FOCUS

IN THIS INVESTIGATION YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ extracting information from observations of a physical model
- ▶ using cause-and-effect relationships to identify scientific problems.

Geologists use models to examine cause-and-effect relationships to help them understand and predict many of Earth's processes. As you have learned in this chapter, many geological processes occur at such slow rates they can be hard for us to observe.

For example, the movement of an ocean floor is too slow for us observe directly. For these types of processes, scientists can only use models to describe and predict cause-and-effect relationships. You will use a physical model in this investigation to explore and explain the cause and effect of seafloor spreading.

MODELLING SEAFLOOR SPREADING

AIM

To construct a physical model to explore how seafloor spreading causes seafloor of different ages to form

Safety

Take care to avoid injuries when using scissors to cut cardboard.

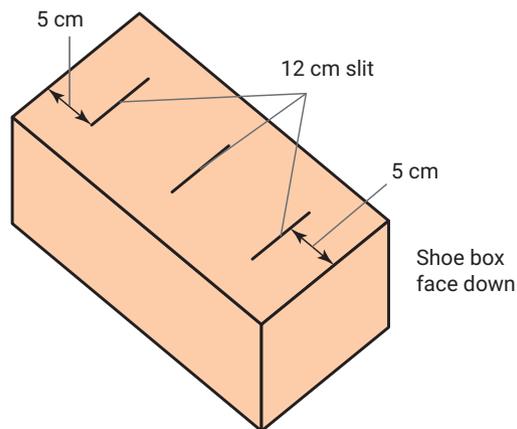
MATERIALS AND EQUIPMENT

- ☑ scissors
- ☑ copies of Worksheet: Modelling seafloor spread
- ☑ shoe box
- ☑ coloured markers



PROCEDURE

- 1 Turn the shoe box upside down so the opening is facing down towards the desk. Cut a 12-cm slit parallel to the short edges in the middle of the shoebox (Figure 17.9.1).
- 2 Cut a similar slit at each end of the shoe box about 5 cm in from each of the short edges.



▲ FIGURE 17.9.1

- 3 Fold the activity sheet in half lengthwise. Use the scissors to cut along the fold line.
- 4 Put the two sheets together so the words 'START' face each other.
- 5 Insert these two sheets up through the centre slit of the shoe box and pull up towards the side slits.
- 6 Insert the ends of each sheet through the end slits.
- 7 Take it in turns to pull the sheets up through the centre slit and down through the side slits. You should pull them up evenly.
- 8 Now start again and reset all your sheets. Pull the sheets up a few centimetres at a time and stop. Each time you stop, draw a wide stripe (about 2–3 cm) across each of the two sheets, using the same-coloured marker.
- 9 Keep pulling out more of both sheets and drawing a stripe with a different-coloured marker each time.

ANALYSIS

- 1 What is represented by the central slit? What feature occurs at the corresponding location on the seafloor?
- 2 What is represented by the side slits? What feature occurs at the corresponding location on the seafloor?
- 3 In this model, what is represented by the stripes? What do the different-coloured stripes represent?
- 4 If you were to sample and date the rocks starting from the central slit and moving to the outside slits, what would you find?
- 5 How could you improve this model to better demonstrate seafloor spreading?
- 6 What additions could you make to your model to better demonstrate magnetic striping?

CONCLUSION

Summarise how well your model showed the process of seafloor spreading. Remember to include the limitations of your model and how you can improve it.

17.10 Earthquakes and volcanoes

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ explain the causes and locations of earthquakes, volcanic eruptions and tsunamis
- ✓ list examples of famous earthquakes, volcanic eruptions and tsunamis.



Video activities
What is a volcano?

What is an earthquake?

Extra science investigation
Modelling P and S waves

GET THINKING

Why do earthquakes and volcanoes occur at some places and not others? What causes them?

Plate boundaries, earthquakes and volcanoes

Each year, enormous amounts of energy are released around the world by earthquakes and volcanic eruptions. As you have learned, most volcanoes and the origins of earthquakes are located along tectonic plate boundaries. Figure 17.5.2 (p. 601) shows the distribution of earthquakes and volcanoes around the world.

Volcanoes

A **volcano** is an opening in Earth's crust through which molten rock reaches the surface (Figure 17.10.1). Molten rock beneath Earth's surface is called **magma**, and magma that has erupted through Earth's surface is called **lava**. Magma contains dissolved gases, and when magma approaches Earth's surface, the gases can escape.

The ability of magma to flow is affected by the amount of silicon dioxide present and the temperature of the magma. At divergent boundaries, magmas have a low **viscosity** and therefore flow readily. Gas escapes easily from the lava and explosions are rare. At convergent boundaries, magmas are more viscous. This is because the magma composition changes as some mineral crystals form, which removes elements from the liquid. The remaining liquid contains a higher proportion of silica dioxide and has higher viscosity.

volcano

an opening in Earth's crust, through which molten rock reaches the surface

magma

extremely hot liquid or semi-liquid rock formed under the surface of Earth

lava

hot, molten rock that is expelled during a volcanic eruption

viscosity

a liquid's resistance to flowing



▲ FIGURE 17.10.1 Volcanoes such as these form at convergent boundaries.

The shapes of volcanoes and the types of eruptions they produce depend on the gas content and viscosity of the magma. At divergent boundaries, lava is hot and runny. It escapes from long fractures or cracks called **fissures** and flows easily. On land, these eruptions are called fissure eruptions (Figure 17.10.2). If the lava erupts from a central opening, called a **vent**, a shield volcano may form. Shield volcanoes are very large but have very shallow sloping sides. Mauna Kea, on Hawai'i, is an example of a shield volcano.

At convergent boundaries, volcanoes eject large amounts of ash through a central vent. The ash comprises small fragments of volcanic glass and rock created by expanding bubbles of trapped gas that break apart the rapidly cooling lava. The gases force the ash high into the sky.

The ash falls and creates a steep-sided volcano called a stratovolcano (Figure 17.10.3). A stratovolcano takes tens to hundreds of thousands of years to form. Its lavas are more viscous than those created at divergent boundaries.

fissure

a long fracture or crack from which lava erupts

vent

the central opening of a volcano



▲ FIGURE 17.10.2 A fissure eruption



▲ FIGURE 17.10.3 A stratovolcano eruption

Earthquakes

An earthquake is a violent shaking of the ground caused by energy-carrying waves passing through Earth. Earthquakes can cause buildings and other structures to collapse. They can also cause landslides. At plate boundaries, enormous forces act on the rocks. Eventually rock breaks or rocks slide past each other on a fault. When they do, they release stored potential energy, which transforms to kinetic energy in the form of an earthquake. Most earthquakes occur at plate boundaries, but earthquakes regularly occur away from plate edges. The cause is the same as at a plate boundary, but there is usually less energy released.

The place where earthquake energy is released is called the **focus** (plural: foci) of the earthquake. The point on the Earth's surface directly above the focus is called the **epicentre**. In subduction zones, the earthquake focus may be as deep as 700 kilometres below the surface.

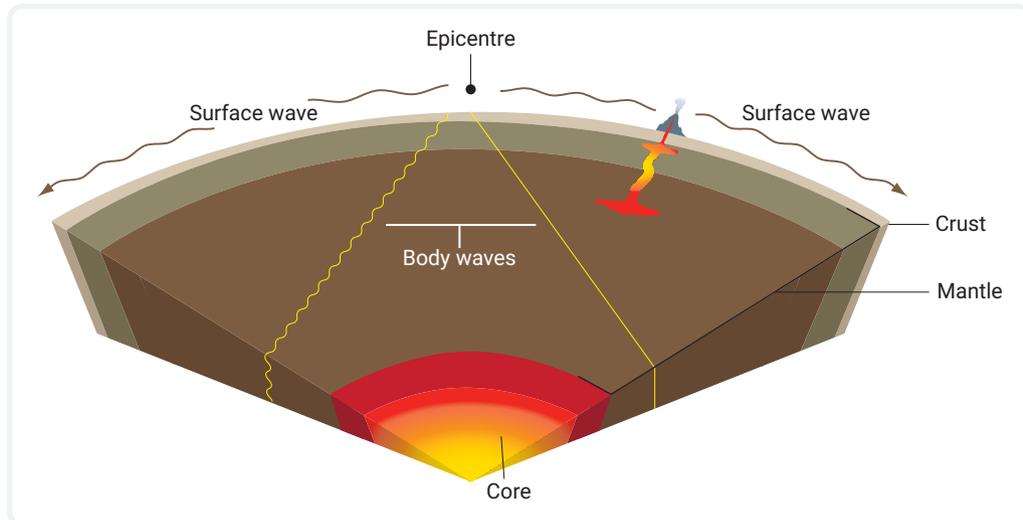
focus

the place where earthquake energy is released

epicentre

the point on Earth's surface directly above an earthquake focus

As the energy moves away from the focus, it travels as different types of waves. Earthquake waves that travel deep below the surface are called body waves, and waves that travel close to the surface are called surface waves (Figure 17.10.4). Surface waves cause the greatest shaking in an earthquake. Fortunately, they become less energetic as they move further away from the focus.



▲ FIGURE 17.10.4 Body and surface waves

Earthquakes are measured by the energy or by the effects they produce. The energy is measured as an earthquake magnitude. The effects are described as intensities. Small earthquakes (magnitude 0–2) are very common but huge ones (magnitude 8 or higher) are very rare (Table 17.10.1). The magnitude scale does not increase in a regular way. Each increase of 1 in the scale is an increase of 10 times the energy. This means a magnitude 3 earthquake has 10 times more energy than a magnitude 2 earthquake and a magnitude 4 earthquake has 100 times more energy than a magnitude 2 earthquake. Each year, there are about 100 earthquakes of magnitude 3 or higher in Australia.

▼ TABLE 17.10.1 Global earthquake magnitudes and frequencies

Earthquake magnitude	How many occur in a year?	Earthquake effects
Less than 2.0	Several million	Rarely seen or felt by people
2.0–2.9	More than a million	A few people see and feel it
3.0–3.9	More than 100 000	Many people see and feel it; ceiling lights swing
4.0–4.9	More than 10 000	Most people see and feel it; walls crack
5.0–5.9	More than 1000	Damages buildings near epicentre; furniture moves
6.0–6.9	More than 100	Causes great damage around the epicentre
7.0–7.9	10–20	Damages most buildings
8.0–8.9	1	Causes major damage to buildings and other structures
9	About one every 10 years	Causes most buildings to collapse and destroys bridges and roads

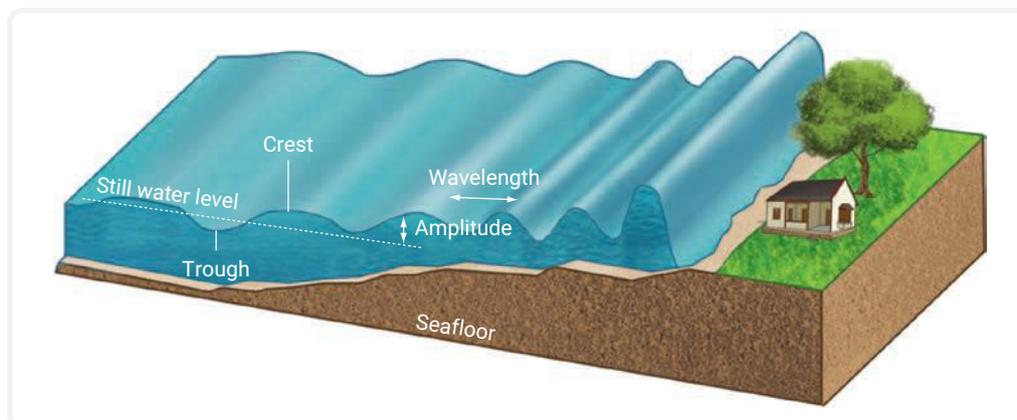
Tsunamis

Earthquakes are the major cause of large, powerful ocean waves called **tsunamis**. Most tsunamis are generated by the sudden movement of the seafloor at convergent boundaries. The sudden movement causes the water above the seafloor to move up or down. As the water flows back, it generates a series of waves that rapidly move outwards. Tsunamis can also be created by undersea landslides, volcanic explosions or meteorite impacts.

A tsunami causes damage when it reaches the shore. As it approaches the shore, the waves slow and increase in height (Figure 17.10.5). When the waves reach the shore, they surge inland, destroying buildings and carrying away anything that cannot resist the surge of water.

tsunami

a series of large ocean waves created by an undersea earthquake or volcanic eruption



▲ FIGURE 17.10.5 As a tsunami enters shallow water, the waves slow down but their height (amplitude) increases.

In March 2011, an area of seafloor 300 km long and 150 km wide near Japan was thrust 10 metres upwards, causing a magnitude 9.0 earthquake. This created a tsunami that rapidly moved away from the epicentre. The Japanese city of Sendai was only 180 km from the epicentre. The tsunami was 11 metres high when it reached the coast and it travelled up to 10 km inland, causing enormous damage and loss of life. More than 19 000 people died.

17.10 LEARNING CHECK

1 Define:

- a earthquake.
- b volcano.
- c tsunami.

2 How is lava different from magma?

3 Name the type of plate boundary where stratovolcanoes are found.

4 Describe where earthquakes occur and explain why they occur there.

5 Explain why damage to coastal communities can occur due to a tsunami and the earthquake that caused it.

17.11

Records of geological events in Australia

**IN THIS MODULE,
YOU WILL:**

- ✓ explore how the cultural narratives of Aboriginal and Torres Strait Islander Peoples provide records of geological events that occurred in Australia many thousands of years ago.

Cultural narratives of volcanic eruptions

Although Australia has no active volcanoes and damaging earthquakes don't happen very often, this wasn't always the case. Thousands of years ago, Aboriginal and Torres Strait Islander Peoples experienced active volcanoes and major earthquakes that helped to shape Australia.

With more than 60 000 years of recorded habitation, Aboriginal Peoples have one of the longest continuing cultural histories connected with a single geographical region in the world. Their knowledge has been passed from generation to generation through oral traditions and it provides details of geological events that can be dated back tens of thousands of years.



▲ **FIGURE 17.11.1** Budj Bim is an extinct volcano in south-west Victoria.

The Gunditjmara Peoples of south-west Victoria are the traditional owners of the Budj Bim World Heritage-listed area, which includes the Budj Bim volcano (Figure 17.11.1). The Gunditjmara Peoples have a cultural narrative that explains the formation of their Country. It describes four giants who gave life and laws to the land. During this period, one ancestral being, Budj Bim, emerged and revealed himself to the surrounding landscape during a volcanic eruption. Lava produced by the volcano has been dated at around 37 000 years old, so it is thought that the narrative could be one of the oldest ever told. The description in the narrative may also demonstrate deductive reasoning about the local geology by the Gunditjmara Peoples.

The Kinrara crater is in north Queensland. Cultural narratives of the Gugu Badhun Peoples tell of a pit forming in the plains, dust filling the air and a river of fire emerging from the ground. The lava flows, which were up to 55 km long, are still clearly visible. The volcanic rocks formed from the eruption of Kinrara have been dated at around 7000 years old, making this one of Australia's youngest eruptions. Some people have suggested these dates potentially mean the story of the eruption has been passed down through more than 230 generations, a period longer than the earliest written records.

Recent volcanic activity in far north Queensland has been dated to more than 10 000 years ago. Cultural narratives describing the volcanic eruptions that formed Eacham (Figure 17.11.2), Barrine and Euramo crater lakes in far north Queensland are well documented.

The Ngadjon-Jii Peoples' cultural narrative explains how two men broke important Ngadjon-Jii laws. This angered the rainbow serpent, an important ancestral being. The narrative explains how the rainbow serpent caused an earthquake and describes the dynamic nature of these events, such as loud noises, violent shaking and the cracking of the earth. The Ngadjon-Jii Peoples' narratives contain not only geological knowledge of volcanic events in the area, but also ecological knowledge. Although the region is now tropical rainforest, the narratives describe it as being covered by eucalypt scrub. Analysis of fossil pollen found in the silt of the crater lakes shows the current rainforest to be approximately 7600 years old. This analysis reaffirms the accuracy and reliability of this narrative, which has impressively remained consistent over more than 200 generations. For many, this illustrates the power of cultural narratives as a way of accurately communicating information across many generations.



Wikipedia/Glpww (CC BY 4.0)

▲ FIGURE 17.11.2 Lake Eacham in far north Queensland was once the crater of a volcano.

For one of the cultural narratives above:

- a relate the events in the narrative to events associated with a volcanic eruption.
- b describe what geological evidence would be present today to confirm that a volcanic eruption occurred.

☆ ACTIVITY 1

Narratives of earthquakes and tsunamis

Knowledge of earthquake activity in the Newcastle region is contained in the men's business oral narratives of the Awabakal Peoples.

The narratives of the Gundungurra Peoples of south-eastern New South Wales and the Kambure Peoples of the Kimberley tell of tsunami events that inundated coastal regions.

In New South Wales, the Barkandji Peoples have a narrative that tells of a great ball of fire falling from the sky, causing tremendous flooding. The narrative then says that the people only survived by running up into the hills. On the eastern seaboard of Australia, scientists have found sedimentary rock layers in the area, dated at around 1500 CE, which show a disturbance that corroborates the oral records of a tsunami occurring in this region. Māori narratives tell of a similar event during a similar timeframe. In 2003, geologists found a 20 km diameter submarine structure in the Tasman Sea south of New Zealand, believed to be an impact crater, with an estimated impact date of approximately 1443 CE and enough energy to have produced a tsunami. This find supports the cultural narratives of a tsunami around that time.



Science History Images / Alamy Stock Photo

▲ FIGURE 17.11.3 Aceh, Indonesia, before (left) and after (right) a huge tsunami in 2004; such events have devastating and long-lasting impacts on communities.

Relate the events in the Barkandji Peoples' cultural narrative to the events associated with a tsunami.

☆ ACTIVITY 2

17.12 Discovering the ocean floor

BY THE END OF
THIS MODULE, YOU
WILL BE ABLE TO:

✓ describe major developments in the study of the seafloor and plate tectonics.



Video activities
Mapping the secrets
of the ocean floor

Our understanding of plate tectonics and how the seafloor forms and changes has evolved over a very long time. Table 17.12.1 is a summary of major discoveries in the development of plate tectonics.

▼ TABLE 17.12.1 A brief history of seafloor discovery and plate tectonics

1872–76	The British <i>Challenger</i> expedition gathered rocks from the seafloor and made depth measurements with weights on ropes, leading to the discovery of ocean trenches. Until this time, people thought the seafloor was flat, ancient and unchanging.
1930s and 1940s	Scientists used echo sounders to discover many young undersea mountains.
1947	Maurice Ewing discovered that the ocean crust is mainly basalts, rather than granites as many people expected.
1950	US scientists discovered that the seafloor has a thin sediment layer and a uniform ocean crust structure. Scientists detected magnetic variations in the ocean seafloor.
1953	Marie Tharp and Bruce Heezen published a map showing an underwater mountain range: the Mid-Atlantic Ridge.
1955	Geologists discovered magnetic striping in the ocean floor, parallel to and symmetrical about mid-ocean ridges.
1956	Scientists found a deep rift valley in the Mid-Atlantic Ridge.
1960	Harry Hess and Robert Dietz proposed the seafloor spreading hypothesis.
1963	Frederick Vine, Drummond Matthews and Lawrence Morley tested the seafloor spreading theory using magnetic data. Their work supported the theory and provided a way to measure the rate of seafloor spreading.
1964	George Plafker studied a large earthquake in Alaska and concluded that the earthquake was caused by the Pacific crust being forced under, or subducted, beneath Alaska.
1965	Canadian J. Tuzo Wilson described and explained transform faults.
1967	Scientists explored the idea of tectonic plates moving relative to each other.
1968	The <i>Glomar Challenger</i> drilled cores adjacent to the Mid-Atlantic Ridge, confirming that ocean crust is young and forms at the mid-ocean ridge.
1995	GEOSAT satellite radar data allowed researchers to map the world's entire ocean floor.

☆ ACTIVITY 1

Plate tectonics timeline

Procedure

- Identify when the following discoveries or concepts occurred using the summary in Table 17.12.1.

<p>a Ocean crust is ancient and unchanging.</p> <p>c Ocean crust is created at mid-ocean ridges.</p> <p>e Trenches</p>	<p>b Ocean crust is young.</p> <p>d Ocean crust is not the same as continental crust.</p> <p>f Subduction zones</p>
---	--



g Mid-ocean ridges

h Transform faults

i Magnetic striping

j Seafloor spreading hypothesis

- 2 Use the information from your answer to question 1 to create a timeline from 1850 to 2000 of these discoveries and concepts.

Analysis

- 1 **Identify** three methods of gathering data that were important in developing the plate tectonics theory.
- 2 What does your timeline show about the rate of discovery up until 1950?
- 3 **Summarise** how our understanding of the ocean floor is different from what people thought in the 1800s.

Calculating the rate of plate spreading

☆ ACTIVITY 2

Using knowledge of when magnetic field reversals happen, scientists can identify the age of the seafloor near a mid-ocean ridge. In this exercise, you will use second-hand data to work out the speed at which an ocean is opening.

Procedure

- 1 Examine Table 17.12.2.

▼ TABLE 17.12.2 Age of seafloor at different distances from a mid-ocean ridge

North of the ridge		South of the ridge	
Distance from mid-ocean ridge (km)	Age of the seafloor (millions of years)	Distance from mid-ocean ridge (km)	Age of the seafloor (millions of years)
0	0	0	0
94	2.6	94	2.6
528	19	470	19
605	23	504	23
1206	50	1180	50
1547	66	1560	66

- 2 Use graph paper to graph the data north of the mid-ocean ridge. Plot distance on the vertical axis and age on the horizontal axis. Remember to label your axes correctly.
- 3 Draw a line of best fit through the points.
- 4 To calculate the average speed that the seafloor is moving, calculate the slope of the line of best fit. Your answer will be in kilometres per million years or millimetres per year.
- 5 Repeat steps 1–3 for the data south of the mid-ocean ridge.

Analysis

- 1 Are the average speeds of the plates north and south of the mid-ocean ridge similar?
- 2 Is the ocean spreading at a constant rate? How can you tell?
- 3 If the ocean is between two continents, how much further apart do the two continents move each year?

17 REVIEW

REMEMBERING

- 1 What name is given to each of the following?
 - a The solid Earth
 - b The largest rocky layer of Earth
 - c The part of Earth composed of solid iron and nickel
 - d The part of Earth composed of liquid metal
- 2 **List** three differences between continental crust and oceanic crust.
- 3 **Name** the type of plate boundary where:
 - a steep sided, ash-erupting volcanoes occur.
 - b rift valleys form at the centre of mountain chains.
 - c low-viscosity lavas erupt.
- 4 **State** the theory of plate tectonics.

UNDERSTANDING

- 5 **Draw** a labelled diagram to show how convection in Earth's mantle occurs.
- 6 Why is oceanic lithosphere less than 180 million years old when oceans have existed for billions of years?
- 7 Use a table to **compare** the locations, effects and causes of slab pull and ridge push.
- 8 **List** the features you would look for to identify a convergent boundary.
- 9 **Explain** why an earthquake could occur at a fault that was not at a plate boundary.

APPLYING

- 10 **Create** a diagram of a divergent boundary and show how stripes of normal and reversed magnetism would be arranged around the boundary.

- 11 Why is a tsunami likely to cause more damage approaching a coast with a shallow beach than a coast with deep water?
- 12 **Explain** whether it would be possible for plate tectonics to occur on a planet with a cold mantle.
- 13 **Write** a statement relating the viscosity of lava and the type of volcanic eruption it produces.
- 14 Duane Hamacher is an Associate Professor of Cultural Astronomy. He has uncovered evidence linking Aboriginal and Torres Strait Islander Peoples' cultural narratives to meteor events with impact craters dating back thousands of years. **Suggest** why he made the statement: 'Aboriginal stories could lead us to places where natural disasters occurred.'

EVALUATING

- 15 Why didn't many scientists believe in continental drift when Alfred Wegener had so much evidence to support his theory?
- 16 If convection occurs in Earth's mantle, **explain** why it might also occur in the outer core.
- 17 Why do earthquakes originate in the subducting plate at a subduction zone?
- 18 The Himalayas and the Andes mountains are both the result of plate convergence. Why are there no active volcanoes in the Himalayas?

CREATING

- 19 **Create** a concept map to show the relationships between plate boundaries, earthquakes, volcanic activity and geographic features such as mountains and trenches.

1 Connect what you've learned

In this chapter, you've learned how plate boundaries shape the surface of Earth and some of the structures that tectonic forces build. Iceland is an island built by a hotspot on top of a divergent boundary. Review the chapter and make a mind map of the features (volcanic activity, earthquakes, geography etc.) you might expect to find in Iceland.

2 Check your thinking

Explain, in terms of plate tectonics, what is happening to form the rift valley in the photograph. What sort of volcanic activity has created the cliffs on the far side of the valley? What types of earthquake activity would you expect to find in Iceland?

3 Get into action

Make a plan to compare Iceland with Australia. Conduct some research about the geology of Iceland. What is the nature of volcanoes in Iceland? What sorts of features are found on Iceland that you might expect to find at a divergent boundary?

Research the geology of Australia. How common are active volcanoes in Australia? Does Australia have mountains? Has it had mountains in the past? Why is Australia such a dry, flat country?

4 Communicate

Use your knowledge and understanding to create a table contrasting the tectonic features of Iceland with the tectonic features of Australia. Your table should have three columns with headings: 'Characteristics being compared', 'Iceland' and 'Australia'.



18

The rock cycle

18.1 Rocks and minerals (p. 624)

Rocks and minerals are the building blocks of the Earth.

18.2 WORKING SCIENTIFICALLY: **Classifying minerals** (p. 627)

Mineral research

18.3 Igneous rocks (p. 628)

Igneous rocks are formed from liquid rock.

18.4 Weathering and erosion (p. 630)

Weathering and erosion change Earth's surface.

18.5 Sedimentary rocks (p. 634)

Sedimentary rocks are made from the products of weathering and erosion.

18.6 Metamorphic rocks (p. 636)

Metamorphic rocks form when rocks are changed by heat and pressure.

18.7 WORKING SCIENTIFICALLY: **Classifying rocks** (p. 639)

Identifying different types of rocks

18.8 The rock cycle (p. 641)

The rock cycle is a model describing the formation and changes that affect rocks.

18.9 Fossils (p. 643)

Fossils are the remains and traces of living things usually preserved in rock.

18.10 ABORIGINAL AND TORRES STRAIT ISLANDER SCIENCE CONTEXTS: **Shaping rocks into tools** (p. 647)

Aboriginal and Torres Strait Islander Peoples have a deep understanding of the properties of rocks and minerals, which they applied to the manufacture of stone artefacts.

18.12 SCIENCE IN CONTEXT: **Dealing with acid mine water** (p. 652)

Mine rehabilitation is essential to reducing the impact that mining has on the environment.

18.11 WORKING SCIENTIFICALLY: **Conducting fieldwork on Country/Place** (p. 650)

Planning to conduct fieldwork on Country/Place



NASA/JPL-Caltech/Cornell/UMinn

This image was taken on Mars by the NASA Spirit rover. It shows a boulder thrown out of a Martian volcano. Do you think the rocks on Mars are very different from those on Earth? Is it possible that life once lived on Mars? If so, how can we know?

In the future, humans may journey to Mars to study the planet and perhaps live there. How can our understanding of the rocks on Earth help us to understand the nature and history of Mars?

- Are you up for the challenge of learning about the geology of Mars?

▲ FIGURE 18.01 Volcanic boulder on Mars

#18 DIVE INTO SCIENCE!

At the end of this chapter, you can complete Science in Depth Study #18. You can use the information you learn in this chapter to complete the project.

Assessments:

- Prior knowledge quiz
- Chapter review questions
- End-of-chapter test
- Depth study: Research project

Videos

- Video activities: Weathering (18.4); Rock cycle (18.8); How do fossils form? (18.9); Cultural reconnection: Mine rehabilitation (18.12)

Science skills resources

- Science skills in practice: Identifying rocks and minerals (18.7)
- Extra science investigations: Crystal formation (18.1); Modelling the rock cycle (18.8)

Interactive resources

- Drag and drop: Igneous rock classification (18.3); How sedimentary rocks form (18.5); Which rock is which? (18.6)
- Label: Volcanic structures (18.3); The rock cycle (18.8); Fossil formation steps (18.9)
- Crossword: Rock types (18.6)

18.1 Rocks and minerals

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ identify minerals based on their properties
- ✓ explain the relationship between rocks and minerals and give examples of each.



Extra science investigation
Crystal formation

GET THINKING

What do you know about rocks and minerals? Write two questions you would like to learn the answers to from this module.

Rocks and minerals

rock
a naturally occurring solid made up of minerals

We see **rocks** every day, but we rarely see them change. Although rocks are not living, they do change over long periods of time and can change from one type to another. In this chapter, you will learn about rock types as well as the forces and factors that cause them to change. But first, let's focus on answering the question: what is a rock?

mineral
a naturally occurring inorganic solid with a neatly ordered crystal structure and characteristic composition

Rocks are naturally occurring solids made up of substances called **minerals**. A mineral is a naturally occurring **inorganic** solid. There are thousands of types of minerals, and some of them are valuable as gems (Figure 18.1.1).

inorganic
a substance not formed from the remains or products of living things



▲ FIGURE 18.1.1 A variety of minerals

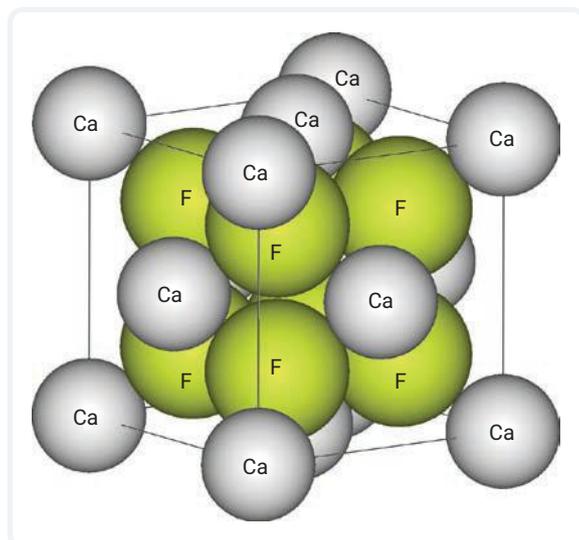
Mineral structure

Minerals have an ordered arrangement of atoms and a characteristic chemical composition. A mineral can consist of a single element or a chemical compound. Gold, sulfur and carbon (diamond and graphite) are naturally occurring elements that are considered to be minerals. But most minerals are chemical compounds and, therefore, can be represented by a chemical formula. For example, fluorite (Figure 18.1.2) has the formula CaF_2 , meaning that it consists of calcium (Ca) and fluorine (F) with twice as many fluorine atoms as calcium atoms.

Sebastian Jamicki/Shutterstock.com



▲ FIGURE 18.1.2 The mineral fluorite



▲ FIGURE 18.1.3 The regular arrangement of calcium (Ca) and fluorine (F) atoms in the mineral fluorite

A mineral's orderly internal structure is called a **crystal** structure. Atoms, or groups of atoms, are arranged in a three-dimensional repeating pattern called a crystal lattice. Figure 18.1.3 shows how calcium and fluorine atoms are arranged in a crystal lattice in fluorite. Mercury, a liquid metal, is the only naturally occurring non-crystalline mineral.

crystal

a solid in which the atoms are arranged in a well-ordered pattern

The crystal structure of a mineral determines its physical properties. Sometimes minerals can have the same chemical composition, but, because they have atoms arranged in different ways, they have different physical properties and are therefore considered to be different minerals. For example, graphite and diamond are both minerals made of carbon. Graphite, the black material in a pencil, is quite soft because the atoms are arranged loosely (Figure 18.1.4a). In a diamond, however, all the carbon atoms are connected strongly to each other in a three-dimensional structure, making the mineral very hard (Figure 18.1.4b).



Fokin Oleg/Shutterstock.com



iStock/peterschreibermedia

▲ FIGURE 18.1.4 (a) Graphite and (b) diamond are minerals with the same chemical composition but different crystal structures.

How minerals are identified

A mineral is identified by its physical properties. Some physical properties are described in Table 18.1.1.

▼ TABLE 18.1.1 Properties of minerals

Property	Description
Colour	Colour can be a useful guide to some minerals. Colour can be produced by small amounts of other elements added to a crystal structure.
Streak	Streak is the colour of a mineral when it is turned into a fine powder. Streak is produced with softer minerals by scraping them across a tile.
Hardness	Hardness refers to how easy it is to scratch a mineral. Mohs scale of hardness (named after the scientist who created the scale) consists of 10 standard minerals (Figure 18.1.5). If one of the 10 standard minerals scratches the unknown mineral, the standard mineral is harder. If it does not, the unknown mineral is the same hardness or harder.
Cleavage	Many minerals tend to split, or cleave, along flat surfaces. These surfaces are called cleavage. There can be more than one direction of cleavage in a mineral.
Lustre	Lustre refers to how light interacts and reflects from the surface of a crystal, rock or mineral. Some minerals are dull, but minerals such as quartz reflect light like glass, and are said to have a glassy lustre.
Density	Density is how tightly packed the atoms are in something. If something is dense, the atoms are very close together. If something is not dense, the atoms are loosely packed.

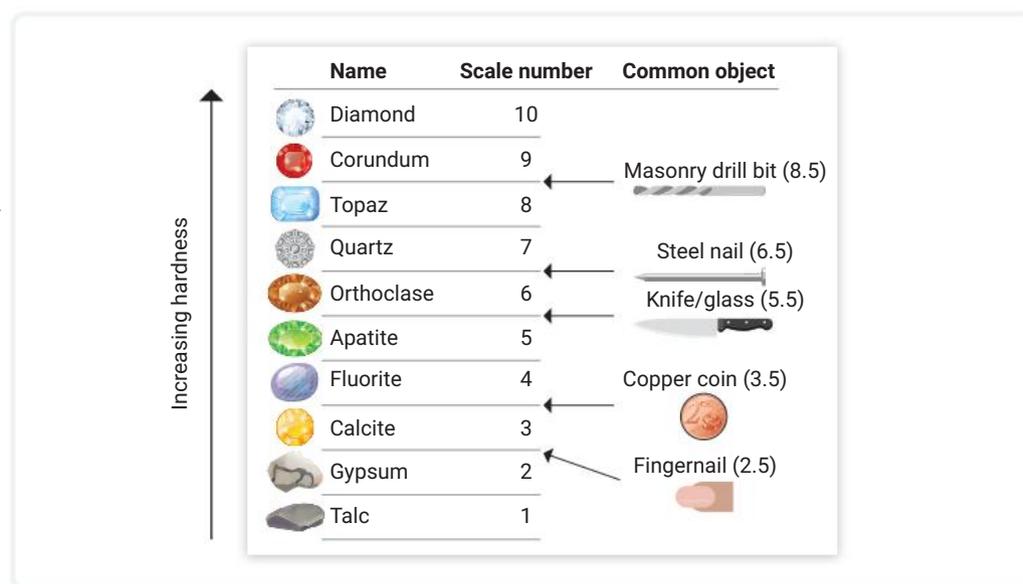
Mohs scale of hardness

a scale used to measure the relative hardness and resistance to scratching between minerals

cleavage

the way a mineral splits to produce a flat surface

National Park Service/U.S. Department of the Interior



▲ FIGURE 18.1.5 Mohs scale of hardness

18.1 LEARNING CHECK

- 1 **Define** mineral.
- 2 **Describe** what defines a mineral.
- 3 **Describe** four physical properties that are used to identify minerals.
- 4 A mineral is found to scratch a sample of calcite but cannot scratch a piece of glass. What is the hardness of this mineral on Mohs hardness scale?
- 5 **Describe** the relationship between rocks and minerals.
- 6 **Explain** how you would tell whether you had a sample of a rock or a mineral.



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ comparing the physical properties of a range of minerals
- ▶ organising data using a table
- ▶ recording observations.

MINERAL RESEARCH

AIM

To describe a range of minerals using their physical properties

MATERIALS AND EQUIPMENT

- five different mineral specimens
- hand lens or magnifying glass
- Mohs scale of hardness test kit
- unglazed ceramic plate

PROCEDURE

- 1 Draw up a table to record your results. It should include six rows (one for the column headings and one for each mineral specimen) and five columns with the headings: 'Specimen', 'Colour', 'Hardness', 'Cleavage and fracture' and 'Special features'.
- 2 Carefully record the colour of each mineral. Note any variations in colour you see.
- 3 Use the Mohs hardness test kit to work out the hardness of each mineral. Do this by trying first to scratch the fluorite test mineral with your mineral specimen. If it does not scratch the fluorite, try the calcite (hardness 3). If it does scratch the fluorite (hardness 4), try the apatite (5) and then orthoclase (6) until you find a mineral your sample cannot scratch. Test each sample until you work out the hardness range (harder than ..., but softer than ...) Record the hardness as a single number or a range in the results table.
- 4 Cleavage or parting surfaces are flat or appear as parallel lines on the surface of the mineral. Try to identify the cleavage planes and the angles between

them. If a mineral breaks unevenly and not along a flat surface, it is called a fracture. Record what you find in the table.

Safety

Beware of small pieces of minerals entering your eyes. Beware of sharp edges on rock specimens. There may be toxic chemicals in the specimens. Wear gloves and safety glasses.

- 5 Look carefully at the specimen. Is there anything that stands out? Does the mineral have a characteristic crystal shape? Does it look like a metal? Does it feel heavy? Record what you see and feel.

RESULTS

Make sure your table is complete and has a title.

ANALYSIS

- 1 Identify the property that was the easiest to determine.
- 2 Did any minerals have the same properties?
- 3 Which mineral was the hardest? Which was the softest?
- 4 What was the most difficult property to work out? Why do you think this was so?

CONCLUSION

Did the properties allow the different minerals to be described? Write a conclusion that summarises your findings. Make sure it relates to your aim.

18.3 Igneous rocks

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

✓ describe the origin and features of intrusive and extrusive rocks.



Interactive resources
Drag and drop: Igneous rock classification

Label: Volcanic structures

GET THINKING

What do you think of when you read or hear the word 'lava'? How many types of material can liquid rock become when it cools?

The formation of igneous rocks

igneous rocks

rocks formed when molten materials (magma or lava) cool and solidify

Igneous rocks are formed from liquid rock, called magma, that comes from deep inside Earth.

As you learned in Chapter 17, if magma reaches Earth's surface, it loses its dissolved gases and is called lava (Figure 18.3.1). When magma or lava cools, it crystallises and solidifies to form solid rock.

The size of mineral crystals in an igneous rock depends on how quickly the liquid rock has cooled. Magma that cools slowly, kilometres below the surface of Earth, results in large crystals – big enough to see without a microscope. If lava cools rapidly at the surface, the crystals are very small – too small to see with your eye alone.



▲ FIGURE 18.3.1 A lava flow showing a rapidly cooled surface broken by the fluid lava underneath

intrusive

describes an igneous rock formed from magma below the surface of Earth

extrusive

describes an igneous rock formed from lava at or above the surface of Earth

pyroclastic

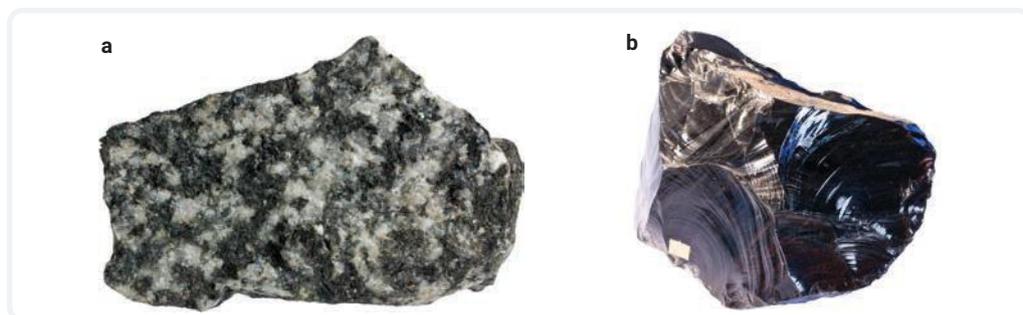
describes rock formed from volcanic ash and rock fragments

Intrusive and extrusive igneous rocks

Igneous rocks formed deep within Earth are called **intrusive** rocks.

It may take thousands or even millions of years for the magma to become solid. Examples of intrusive rocks are granite, diorite, dolerite and gabbro (Figure 18.3.2a).

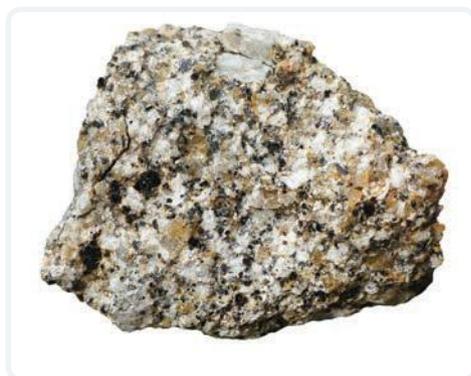
Extrusive rocks crystallise on Earth's surface. Examples of extrusive rocks are basalt, andesite, obsidian and rhyolite. Obsidian is an extrusive rock that cools very rapidly (Figure 18.3.2b). It is a volcanic glass because it cools so fast that crystals do not have a chance to form. Volcanic ash forms when cooling lava is shattered by escaping gas, forming tiny fragments of glass. Ash and larger rock fragments may be joined together, and the resulting rocks are called **pyroclastic** rock.



▲ FIGURE 18.3.2 (a) Gabbro, an intrusive igneous rock; (b) obsidian, an extrusive igneous rock

Identifying igneous rocks

Igneous rocks are classified according to the minerals they contain (composition) and their grain size (texture). Some magmas produce minerals rich in silicon, aluminium and potassium, which create light-coloured minerals. Other magmas, rich in iron, magnesium and calcium, produce minerals that make the rocks appear dark. Rocks such as granite have crystals large enough to see and are called coarse-grained (Figure 18.3.3). Rocks such as basalt, with crystals too small to see, are called fine-grained (Figure 18.3.4). Table 18.3.1 shows some common igneous rocks and their characteristics.



Yes058 Montree Nanta/Shutterstock.com

▲ FIGURE 18.3.3 Granite – an intrusive rock. The individual mineral crystals are 3–4 mm in diameter.



TuktraBaby/Shutterstock.com

▲ FIGURE 18.3.4 Basalt – an extrusive rock

▼ TABLE 18.3.1 Igneous rocks are classified by composition and texture

Composition		Light coloured	Intermediate	Dark coloured
Minerals present		Quartz, potassium and sodium feldspar, mica	Feldspar, hornblende, biotite	Pyroxene, calcium-rich feldspar, some olivine
Texture (grain size)	Coarse-grained examples	Granite	Diorite	Gabbro
	Fine-grained examples	Rhyolite	Andesite	Basalt
	Porphyry (mixed crystal sizes)	<ul style="list-style-type: none"> Named after the large crystals present; for example, feldspar-porphyry Can be named for the type of rock; for example, a porphyritic basalt 		
	Glassy	<ul style="list-style-type: none"> Obsidian – a solid volcanic glass Pumice – a rock formed from gas trapped in glass 		
	Pyroclastic (fragments)	<ul style="list-style-type: none"> Volcanic breccia – angular fragments larger than several millimetres across Tuff – rock formed from ash fragments less than 2 mm in diameter 		

18.3 LEARNING CHECK

- 1 What does the average crystal size of an igneous rock indicate about where the rock formed?
- 2 What do all igneous rocks have in common?
- 3 **Describe** the two key features used to describe and identify igneous rocks.
- 4 Locate a building in your area built using igneous rock. **Describe** the minerals in the rock and **explain** how the size of the mineral crystals relates to its formation.

18.4 Weathering and erosion

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe how weathering and erosion change rocks and create sediments.

GET THINKING

weathering

the breakdown of minerals and rocks at Earth's surface by physical or chemical processes

Look at the key words in the margins of this module. What do you already know about these terms/processes? Can you identify examples where these processes have affected landscapes in your area?



▲ FIGURE 18.4.1 This rock is being weathered. How can you tell?

Weathering

Rocks do not exist forever. Zircon minerals dated as being more than 4 billion years old have been found embedded in rocks at Jack Hills in Western Australia. However, these rocks are not as old as the minerals inside them. So where are the original rocks that contained the minerals?

The breaking down of rocks and minerals by natural processes is called **weathering**. Scientists believe that the minerals found at Jack Hills originated in rocks that have weathered (and metamorphosed – see Module 18.6) over time.

☆ ACTIVITY 1

Introduction to weathering

Materials and equipment

- course-grained granite
- magnifying glass
- mortar and pestle

Procedure

- 1 Observe a sample of coarse-grained granite with a magnifying glass. How many different minerals can you see? Describe them in your notes.
- 2 Grind a small sample of granite to a coarse sand using a mortar and pestle.
- 3 Observe the ground-up granite with a magnifying glass. How have the minerals changed?
- 4 Describe your observations in your notes.
- 5 Keep the ground-up granite for Activity 2.

Analysis

- 1 Did all the minerals grind up in the same way? Can you suggest a reason why?
- 2 Why is this an example of weathering?

⚠ Safety

Always wear safety glasses during this experiment and listen to your teacher's instructions. Remember to grind the rock; don't pound it.

Physical weathering

The effects of changing temperature on rocks, or the effects of water, can break a rock into smaller pieces. This is called **physical weathering**. Physical weathering is common in cold conditions or where temperatures change a lot each day.

A common type of physical weathering is freeze–thaw, or ice wedging. Water seeps into cracks in a rock during the day and freezes into ice at night. The ice expands as it forms, eventually splitting the rock (Figure 18.4.2).

Salt crystals growing between mineral grains can also cause rock to break down. Wind may carry sand or ice, which wears down and polishes rocks. Rocks may also undergo physical weathering when other rocks are removed from above them. Removing the top rocks leads to a release of pressure, causing the underlying rocks to expand and split.

Chemical weathering

When the chemical composition of minerals in a rock are changed by air or water, this is called **chemical weathering**. Chemical weathering occurs when minerals in the rock are changed by chemical reactions. Water can dissolve minerals. Acids can change minerals too. The red and yellow colours of some rocks are due to iron reacting with oxygen (Figure 18.4.1).

physical weathering

a process of weathering that breaks rocks apart or wears them down, but does not change their chemical composition

chemical weathering

a process of weathering that changes the chemical composition of the minerals in rocks



Nature Picture Library / Alamy Stock Photo

▲ **FIGURE 18.4.2** Freeze–thaw weathering occurs as ice wedges open cracks in a rock.

Investigating chemical weathering

☆ ACTIVITY 2

Materials and equipment

- ground granite from Activity 1
- mortar and pestle
- water
- wash bottle
- filter funnel
- filter paper
- medium-sized test tube
- test-tube rack
- 10 mL measuring cylinder

Procedure

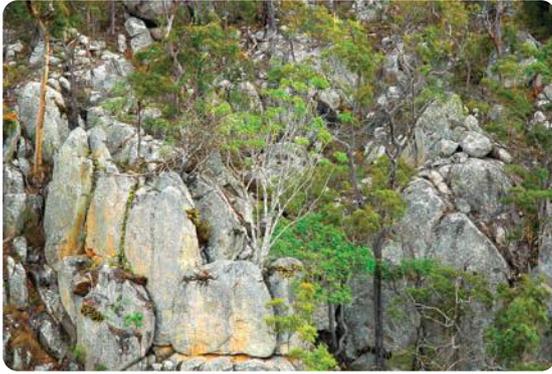
- 1 Add about 5 mL of water to the ground granite in a mortar and grind the material for 3 minutes. Record what you see in your notes.
- 2 Place the filter paper in the filter funnel. Place the funnel in the top of a medium-sized test tube that is sitting in the test-tube rack. Wash all the sediment into the filter paper with a wash bottle.
- 3 Observe the liquid in the test tube and the material on the filter paper. Describe what you see in your notes.

Analysis

- 1 The white precipitate is the result of water reacting with feldspar. Why is this a chemical reaction?
- 2 **Discuss** with your teacher how you might test for the presence of salts in the water once the precipitate settles.

⚠ Safety

Always wear safety glasses during this experiment and listen to your teacher's instructions. Remember to grind the rock; don't pound it.



▲ **FIGURE 18.4.3** Biological weathering. How will the tree roots split the rock?

biological weathering
a process of weathering in which living organisms break down rocks

erosion
the movement of weathered material away from where it forms by water, wind, ice or gravity

sediment
solid material transported from one place and deposited in another

transportation
the movement of solid particles by agents of erosion over large distances

deposition
the laying down of sediment

Biological weathering

Living things can also break down rocks. This is called **biological weathering**. Biological weathering takes many forms. Some are physical processes and others are chemical processes. Plant roots can split rocks (Figure 18.4.3). Lichens can release acids that dissolve some minerals. Bacteria and fungi can also chemically weather minerals.

Erosion

Weathering usually produces three types of material: rock and mineral fragments, clay minerals and dissolved salts. **Erosion** is what happens when the weathered materials move away from their original location. Wind, water, ice and gravity can relocate weathered material. These are called agents of erosion. Wind can carry fine sand and dust; ice can move rocks the size of a house. Erosion usually happens slowly, over many years, but sometimes it can happen suddenly (Figure 18.4.4).

Transportation

The solid material being transported in erosion is called **sediment**. The movement of sediment by agents of erosion over large distances is called **transportation**. Water can carry sediment in rivers or move material by wave action on a coast. Over time, rock fragments on a steep slope can slide downhill. As rocks are transported, they change. For example, as rocks are carried down a river, they become rounder, smaller and more spherical due to abrasion by other rocks and mineral grains (Figure 18.4.5). Soft minerals (e.g. mica or calcite) are ground down by harder rocks until only hard minerals such as quartz remain.

Deposition

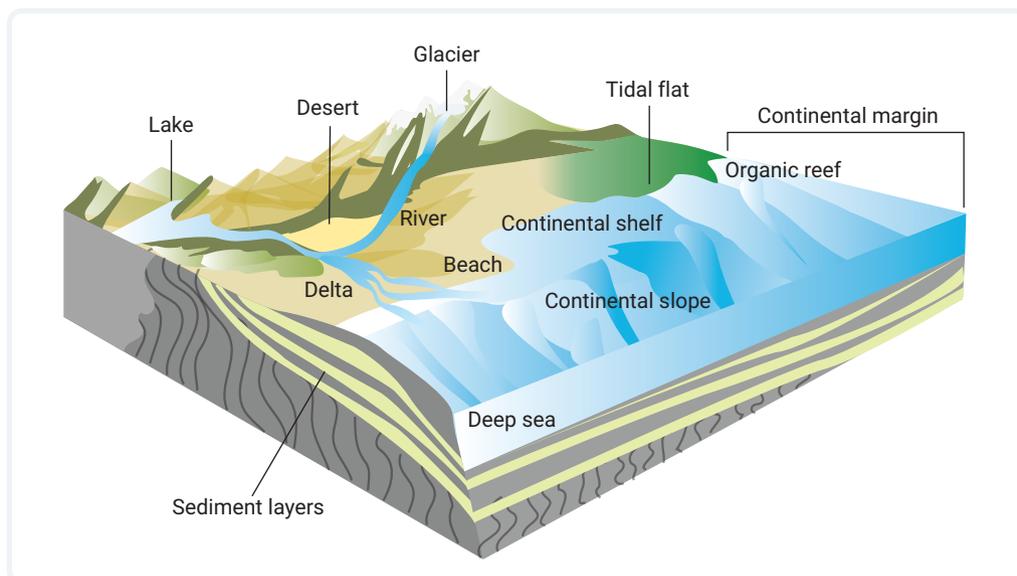
Deposition is the process in which sediments, soil and rocks build up at a location. In fast flowing water, heavy sediments such as pebbles can settle out. Slow flowing water allows lighter sediment such as sand grains to settle out. Very still water allows tiny mud and clay particles to settle to the bottom. Environments of sediment deposition are shown in Figure 18.4.6.



▲ **FIGURE 18.4.4** Rock falls can happen very quickly.



▲ **FIGURE 18.4.5** What has rounded these pebbles?



▲ FIGURE 18.4.6 Common sedimentary environments

Sediment settling

☆ ACTIVITY 3

Materials and equipment

- 250 mL measuring cylinder
- dry soil
- water
- plastic wrap

Procedure

- 1 Fill the 250 mL measuring cylinder to the 40 mL mark with dry soil.
- 2 Fill the measuring cylinder to the 70 mL mark with water.
- 3 Tightly cover the top of the measuring cylinder with plastic wrap.
- 4 Hold the base of the measuring cylinder with one hand and cover the top with your other hand. Shake the measuring cylinder vigorously.
- 5 Place the measuring cylinder on a bench and observe what happens.

Analysis

- 1 What did you observe?
- 2 Why do you think this happened?
- 3 What made the water coloured? Will it stay this way?
- 4 Summarise what the results of the activity show about deposition of sediments.

! Safety

Always wear safety glasses during this experiment and follow your teacher's instructions.

18.4 LEARNING CHECK

- 1 **Describe** the process of weathering using an example.
- 2 **List** the agents of erosion.
- 3 **Explain** the relationship between weathering and erosion.
- 4 **Compare** weathering and erosion in terms of the agents involved.
- 5 **Explain** how the speed of flowing water is related to the types of sediment moved by the water.



Quiz
Types of weathering

Video activity
Weathering

18.5 Sedimentary rocks

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

✓ describe the origins and types of sedimentary rocks.



Interactive resource
Drag and drop:
How sedimentary
rocks form

GET THINKING

Skim read the headings and images of the two pages of this module. What do the headings and images tell you about this module?

How sedimentary rock forms

Sedimentary rocks are formed from the products of weathering and erosion. Small pieces of rocks and minerals, clays and salts can all form sedimentary rocks. The remains of once-living organisms can also be buried in sediments and become rock.

Sediments such as sand or mud become rock when they are compacted and cemented together. Sediment is laid down in water in layers. Over time, more sediment is deposited on top. As the sediment builds up, the weight of the sediment forces particles closer together. This process is called **compaction**. Although the sediment grains are close together, water can still move through tiny spaces between the grains. Minerals dissolved in the water crystallise on the surfaces of the sediment, forming cement that binds the sediment together. This process is called **cementation** (Figure 18.5.1). Because sedimentary rocks form from layers of sediment deposited on top of one another, sedimentary rocks form horizontal layers called **beds** (Figure 18.5.2).

sedimentary rocks

rocks formed from sediments

compaction

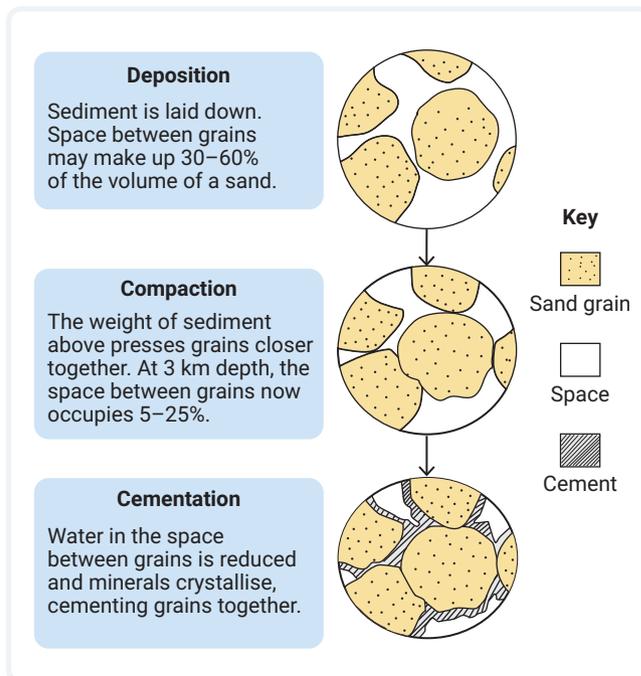
the process whereby pressure forces particles closer together

cementation

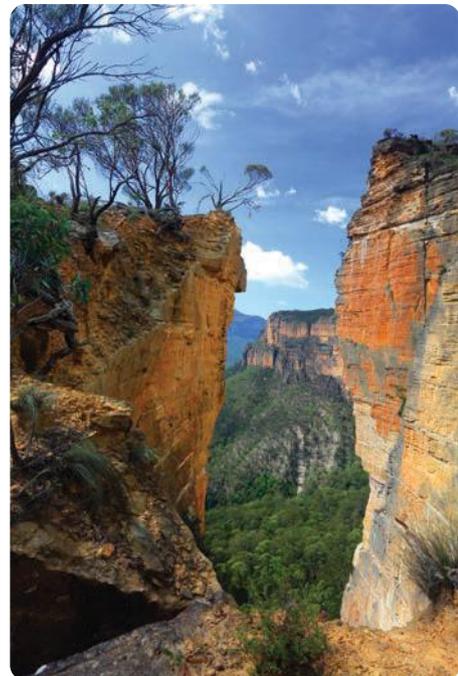
the process whereby new minerals bind sediment grains together

bed

a horizontal layer of sedimentary rock



▲ FIGURE 18.5.1 How sedimentary rocks form



Leah-Anne Thompson/Shutterstock.com

▲ FIGURE 18.5.2 Can you see layers (beds) in the sandstone cliffs? The tree-covered slopes below the cliff are made up of softer sandstones, mudstones and coal layers.

Types of sedimentary rock

Sedimentary rocks can be grouped according to the type of sediment they contain.

- **Clastic** sedimentary rocks: These are made of rock or mineral fragments (clasts) cemented together (Figure 18.5.3). Sandstone is a clastic rock formed from sand-sized particles. Mudstone is formed from clay minerals. Conglomerate is a clastic rock containing rounded pebbles. A layered mudstone is called shale.
- Chemical sedimentary rocks: These are rocks formed from minerals precipitated from water. Some limestones and rock salt are formed in this way.
- **Organic** sedimentary rocks. These rocks are composed of the remains of once-living organisms. Coal is formed from the remains of plants buried in swamps or lakes (Figure 18.5.4). Many microscopic plants as well as corals build shells and hard parts, which can form limestones (Figure 18.5.5). Chalk is a limestone formed from the skeletons of microscopic plants and animals.

Sometimes a sedimentary rock can contain a combination of particles, remains of living things and chemicals. For example, oil shale contains clay minerals but also oil, which has formed from the remains of living things. Clastic rocks often contain fossils – the remains of once-living organisms. We will learn more about fossils in Module 18.9.

clastic

a rock composed of rock or mineral fragments

organic

relating to, or made from, living material



Fokin Oleg/Shutterstock.com

▲ **FIGURE 18.5.3** Conglomerate rock contains rounded pebbles.



SHTRAUS DMYTRO/Shutterstock.com

▲ **FIGURE 18.5.4** Coal is a rock formed from buried plant material and other sediment.



iStock/Rafael_Wiedenmeier

▲ **FIGURE 18.5.5** Limestone is a hard sedimentary rock made of the mineral calcite. It is often formed from the remains of living things. Note the shell impression in this sample.

18.5 LEARNING CHECK

- 1 **Define** sedimentary rock.
- 2 Draw a flow chart to show the processes/steps by which a sedimentary rock forms.
- 3 **Compare** the composition of a sandstone and a coal.
- 4 **Distinguish** between the three groups of sedimentary rocks.
- 5 **Explain** why sedimentary rocks might contain the remains of once-living organisms, whereas igneous rocks do not.

18.6 Metamorphic rocks

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

✓ describe the origins and features of metamorphic rocks.



Interactive resources

Drag and drop:
Which rock is which?

Crossword: Rock types

GET THINKING

How are metamorphic rocks different from other rocks? Scan the module and make a list of differences you notice.

metamorphic rocks

rocks that have been altered by heat, pressure or hot fluids

Types of metamorphism

The minerals in a rock will change over long periods if the rock's environment changes. When rock is buried deep in Earth, increased heat and pressure will cause the rock to change. **Metamorphic rocks** are rocks that have been altered by heat, pressure or hot fluids (Figure 18.6.1).



woe/Shutterstock.com

▲ **FIGURE 18.6.1** Eclogite – a metamorphic rock with a composition similar to volcanic basalt. Eclogites form when ocean crust is buried deep below the surface of Earth.

contact metamorphism

rock metamorphism caused by heat

When rocks are altered by heat, the process is called thermal metamorphism or **contact metamorphism**. Most contact metamorphism is due to heat from magma. When magma rises in the crust, its heat alters the rocks surrounding it. Minerals recrystallise, changing their size and shape. Soft sedimentary shale becomes a hard, tough, dark metamorphic rock called hornfels (Figure 18.6.2). Sandstone, a sedimentary rock, recrystallises into a harder rock called quartzite (Figure 18.6.3). Soft limestones become hard, sturdy marble.



wvoe/Shutterstock.com

▲ **FIGURE 18.6.2** Hornfels – a contact metamorphic rock formed from a clay-rich rock such as shale



Yes058 Montree Nanta/Shutterstock.com

▲ **FIGURE 18.6.3** Quartzite – a dense, hard and glassy rock formed from sandstone

A narrow sheet of magma forced through a crack may only change a centimetre of rock next to it. But near a huge **batholith**, rocks may be changed for hundreds of metres around the igneous rock.

Hot fluids also change rocks. This is known as **hydrothermal metamorphism**. As hot fluids from magma bodies travel through nearby rocks, chemical changes occur. The fluids change the chemical composition of the rocks they pass through by removing some elements and depositing others and causing new minerals to form.

When heat and pressure produce metamorphic rocks, this is known as **regional metamorphism**. Where mountains form, rocks experience both heat and enormous pressure. The source of such pressure is described in Chapter 17. The types of rocks formed depend on the amount of heat and pressure, the original rock, and how long it takes the change to happen.

batholith
a very large volume of intrusive rock, formed deep under Earth's surface by solidification of magma

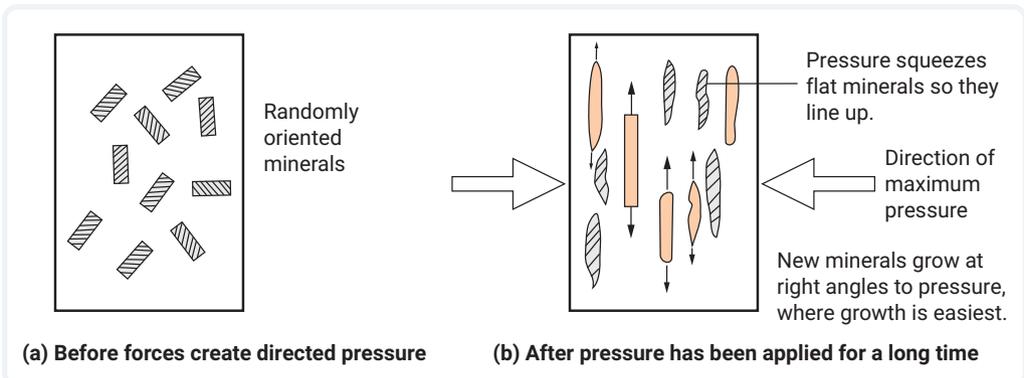
hydrothermal metamorphism
rock metamorphism caused by hot fluids underground changing the chemical composition of rocks they pass through

regional metamorphism
rock metamorphism caused by heat and pressure

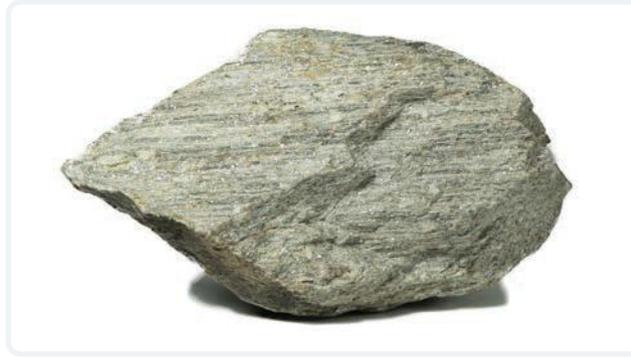
Features of metamorphic rocks

Two characteristics of regional metamorphic rocks are layering and the growth of large crystals in the rock. The layering is called **foliation**. Clay minerals, like the ones found in a mudstone rock, change and grow forming mica minerals. The mica sheets grow at right angles to the direction of maximum pressure because it is easier to grow in that direction (Figure 18.6.4). An example of a rock that does this is a schist (Figure 18.6.5).

foliation
layering in a rock formed by crystal regrowth



▲ **FIGURE 18.6.4** New minerals grow at right angles to the direction of pressure on them.



Rattachon Angmanee/Shutterstock.com

▲ FIGURE 18.6.5 Schist is a rock showing foliation.

Examples of metamorphic rocks are listed in Table 18.6.1.

▼ TABLE 18.6.1 Examples of metamorphic rocks

Type of metamorphism	Original rock type	New rock type	Rock properties
Contact	Limestone	Marble	• Hard
	Sandstone	Quartzite	• Dense
	Mudstone	Hornfels	• Mineral crystals have regrown larger
Hydrothermal	Basalt	Greenstone	• New minerals present • Some hydrothermal rocks contain valuable ore minerals
Regional	Mudstone	Slate	• Foliated
		Schist	• Increasing mineral size
		Gneiss (pronounced 'nice')	• New metamorphic mineral grows in the rocks
	Basalt	Eclogite	• Very dense rock from the upper mantle • Large crystals of garnet surrounded by green pyroxene
		Amphibolite	• Dark • Dense • Poorly foliated • Rich in hornblende and plagioclase feldspar
	Granite	Gneiss	• Hard • Dense • Bands (may be a centimetre or more across) of dark biotite mica and light feldspar/quartz • May be other metamorphic minerals growing in the layers
	Limestone	Marble	• Granular (large crystals) • Dense • Hard, although grains are soft

18.6 LEARNING CHECK

- 1 **Identify** the type(s) of rocks from which metamorphic rocks form.
- 2 **List** the conditions under which contact metamorphic rocks form.
- 3 **Describe** the conditions under which regional metamorphic rocks form.
- 4 **List** four properties of metamorphic rocks.
- 5 **Compare** and **explain** the features of a metamorphic rock formed by heat with one formed by both heat and pressure.



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ using scientific tools to observe and compare properties of different types of rocks
- ▶ employing safe work practices and managing risks
- ▶ proposing inferences based on observations and secondary source information.

In geology, you can use observations to classify rocks. Below is a checklist to help you with your observations.

- Use the right equipment – a microscope or magnifying glass.
- Turn the light on – bright light will make it easier to observe the rocks.
- Have a checklist of what features are you going to be looking for; for example, size, colour, mineral size, hardness.
- Record your findings – a table is often the best way to record your observations but labelled drawings are also a valuable way to record observations.



**Science skills
resource**

Science skills in
practice: Identifying
rocks and minerals

IDENTIFYING DIFFERENT TYPES OF ROCKS

AIM

To classify rock specimens into one of three rock types: igneous, sedimentary or metamorphic

Safety

Some rocks contain minerals that are poisonous. Rocks may also have sharp edges and contain needle-like minerals. Review any potential risks with your teacher before you begin. Wear safety glasses and gloves when you handle the specimens.

MATERIALS AND EQUIPMENT

- 8 unlabelled rock samples
- dissecting microscope and lamp
- hand lens
- pencil
- plain paper

PROCEDURE

- 1 Consider the list of features in Table 18.7.1. In a group, identify which features belong to igneous, sedimentary or metamorphic rocks (refer to modules 18.3, 18.5 and 18.6).
- 2 Draw a results table using the column headings listed in the results section.
- 3 Observe each rock specimen and record your observations in your results table. Use the list of features in Table 18.7.1 as a guide, but you can also observe features such as colour and layers, which might reflect how the rock formed.
- 4 Make a judgement as to the rock type of each specimen. List two or three reasons for your choice.
- 5 Discuss your results with the class and teacher. Your teacher may provide the name of each rock specimen. If so, note it in your results.
- 6 Make a list of the most useful characteristics you used to identify members of each rock type.

▼ TABLE 18.7.1 Diagnostic features of igneous, sedimentary and metamorphic rocks

Feature

- Large (big enough to see) interlocking crystal grains
- Small interlocking crystals, some glitter when moved in the light
- Rounded holes possibly from escaping gas, glassy appearance to some parts of rock
- Rock or mineral fragments cemented together
- Layers of fine-grained material or sand-sized particles cemented together
- Presence of shell or plant fragments in the rock
- Hard, dense with sharp edges
- Layered due to flat lying crystals (foliated structure)
- Large (big enough to see) layered crystal grains
- Presence of large crystals that appear to have grown in the rock

RESULTS

Use the following column headings for your table of observations:

- specimen number
- observations
- inferred rock type
- reasons for choice
- name of rock (optional).

ANALYSIS

- 1 Which rock type was the easiest to recognise? Why do you think so?

- 2 Igneous and metamorphic rocks may both contain large crystals. How can you tell these rock types apart?
- 3 Sedimentary rocks and contact metamorphic rocks can both be fine-grained. What additional features can you use to identify which rock type a sample belongs to?

CONCLUSION

Refer to your results table to write a conclusion for this investigation. Why is it important to have a knowledge of rock features to identify the origin of a rock sample?

18.8 The rock cycle

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

✓ describe the rock cycle and associated energy changes.

GET THINKING

Look at Figure 18.8.1. What does it show? How does it relate different rock types to each other?



Video activity
Rock cycle

Interactive resource
Label: The rock cycle

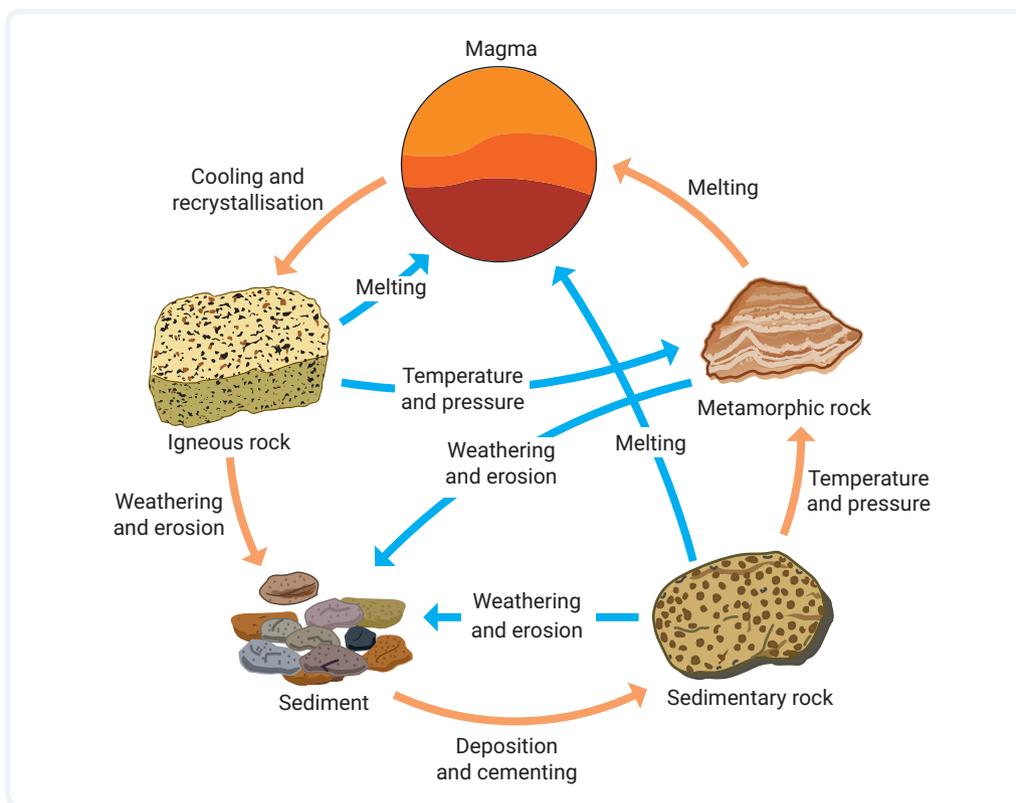
Extra science investigation
Modelling the rock cycle

What is the rock cycle?

Scientists use models to understand the world. A model geologists use to explain how rocks are formed and change is called the **rock cycle**. Consider the diagram of the rock cycle shown in Figure 18.8.1.

The rock cycle shows the processes through which one rock type or material can be changed into another. It is called a cycle because it is possible to move from one substance to another and eventually return to the start.

rock cycle
a model used to explain how rocks are formed and how they change



▲ FIGURE 18.8.1 The rock cycle

Energy changes in the rock cycle

Energy is necessary for change to occur. Heat is needed to melt rocks. A loss of heat causes igneous rocks to crystallise (Figure 18.8.2). Energy is needed to produce the pressure for



▲ FIGURE 18.8.2 This lava flow at Fagradalsfjall in Iceland slowed down as it went down the slope. As it slowed, it cooled and became solid rock.

metamorphism and to alter sediment as it moves down a river. Rocks can be weathered by water, waves and wind (Figure 18.8.3). The heating and cooling of rocks can also cause weathering. Look at the rock cycle (Figure 18.8.1) and see whether you can identify the source of energy needed for the changes that occur.

Even rocks that have been formed deep under the surface of Earth can eventually be exposed. The process whereby underground rocks are raised to the surface is called **uplift** (Figure 18.8.4). As rocks weather and are removed from the surface by erosion, deeper rocks become exposed.



▲ FIGURE 18.8.3 Wind and waves have kinetic energy and they can cause weathering and erosion.



▲ FIGURE 18.8.4 Uplift, weathering and erosion have formed the Bungle Bungle Range in Western Australia.

18.8 LEARNING CHECK

uplift

the process whereby rocks formed underground are raised to the surface

- 1 Draw the rock cycle. Next to each rock type, **write** the names of two examples.
- 2 **Describe** the two processes required to turn a metamorphic rock into an igneous rock.
- 3 **List** the steps needed to turn a metamorphic rock into a sedimentary rock.
- 4 How does an igneous rock become a metamorphic rock?
- 5 At Broken Hill in New South Wales, there are surface rocks that formed more than 20 km below the surface.
 - a **Predict** what type of rocks they are.
 - b **Explain**, using the rock cycle, how those rocks have been exposed at Earth's surface.

18.9 Fossils

BY THE END OF THIS MODULE, YOU WILL BE ABLE TO:

- ✓ describe the conditions under which fossils form
- ✓ explain how the age of fossils can be determined.

GET THINKING

What do you see in the photo in Figure 18.9.1? What is it made of? Was the object once living? If so, was it an animal or a plant?

What is a fossil?

Fossils are the remains or traces of organisms that once lived on Earth, which are mostly preserved in rock (Figures 18.9.1, 18.9.2, 18.9.4 and 18.9.5 all show examples). Fossils formed from the remains of plants or animals are called **body fossils**. Many living things have **hard parts** such as teeth, shells and wood. These hard parts are more likely to be preserved as fossils than soft parts of animals or plants, because they are less likely to break down or lose their shape. However, soft-bodied animals have left impressions in ancient rocks. Insects trapped in amber (the hardened phloem sap of ancient trees) have provided important information about how insects have changed over time. Sometimes, a metamorphic rock may contain fossils if the rock is not changed very much.

Footprints, body impressions, fossilised faeces and preserved burrows are also fossils. Although these are not formed by the actual body remains of a living thing, they are structures or impressions left by the living thing. These are called **trace fossils** (Figure 18.9.2). They tell us how animals lived and moved even when the animal's remains are not present. Carvings and other objects made by humans are called **artefacts** and they can sometimes be confused with fossils.



▲ FIGURE 18.9.1 An example of a fossil



▲ FIGURE 18.9.2 A dinosaur footprint is a trace fossil.

Going further: how big was that dinosaur?

Scientists have developed some rules to work out the size of a dinosaur from its footprint. They:

- measure the length of the footprint
- multiply the length of the footprint by 4 to estimate the height of the dinosaur's hip
- multiply the length of the footprint by 10 to estimate the head-to-tail length of the dinosaur.

Try it. Use the hand in Figure 18.9.2 to estimate the length of the footprint in centimetres, then work out the other lengths.

☆ ACTIVITY 1

fossil

the remains or traces of living organisms, preserved in rock

body fossil

a fossil formed from the remains of a plant or an animal

hard parts

refers to the hard parts of an organism's body, such as shells, bones and teeth

trace fossil

a structure or an impression left by a plant or animal, which shows that life existed

artefact

an object made by a human being

lithification

the process whereby a sediment under compaction becomes a rock

mould

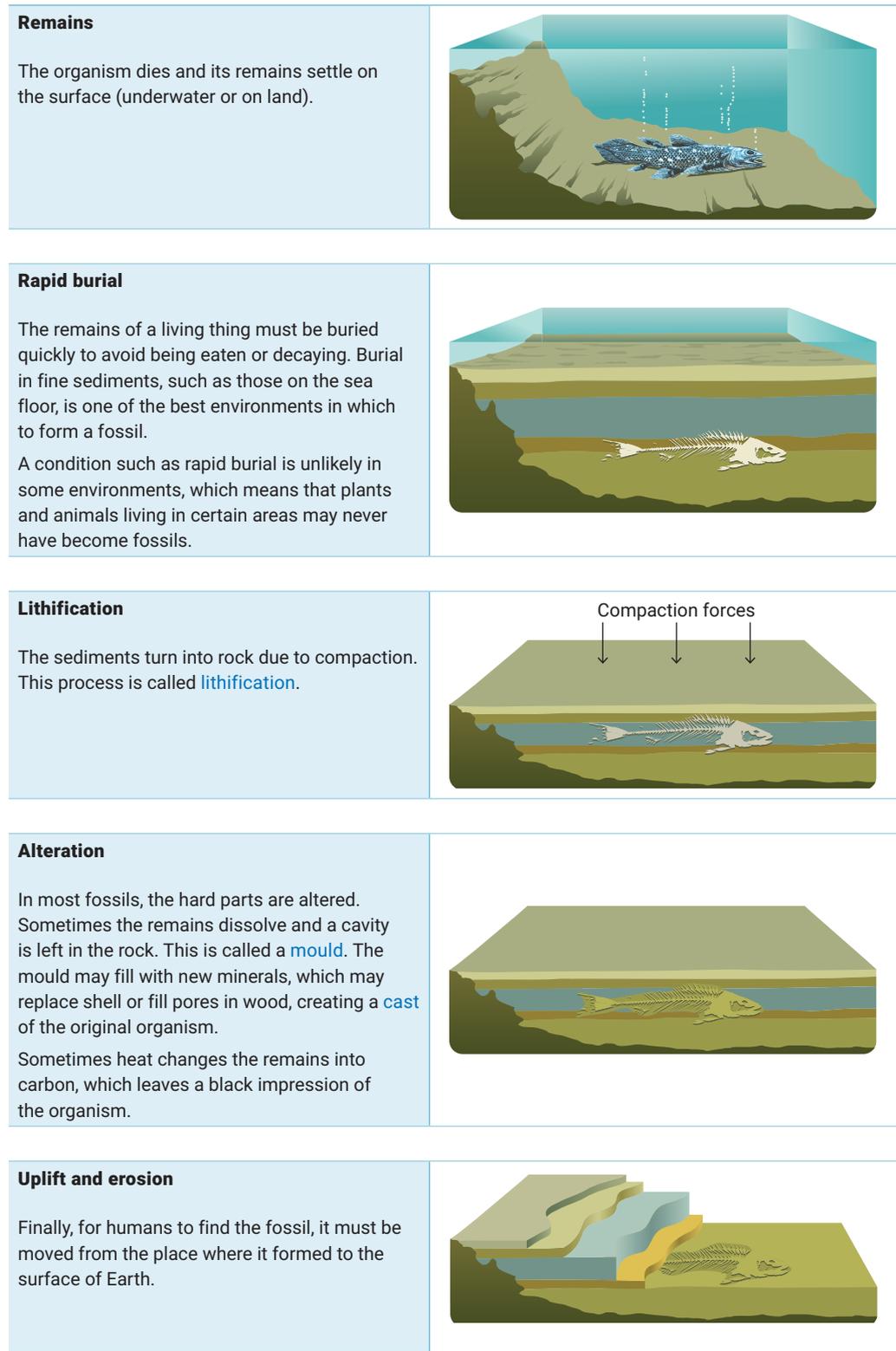
a fossil made in the shape of a plant or an animal's remains after those remains have dissolved

cast

a fossil formed when minerals fill a fossil mould

How fossils form

Figure 18.9.3 shows the steps involved in fossil formation.



▲ FIGURE 18.9.3 Fossil formation



Breck P. Kent/Shutterstock.com

▲ FIGURE 18.9.4 A cast (left) and mould (right) of an trilobite fossil



Kevin Schafer/Getty Images

▲ FIGURE 18.9.5 A fossil of dinosaur bones. Most of the bone has been replaced by minerals.

Modelling fossils

☆ ACTIVITY 2

Materials and equipment

- leaf or shell
- plasticine or playdough
- disposable cup
- plaster powder
- water
- icy-pole stick for stirring

Procedure

- 1 Mould the plasticine into a rectangular prism or cube shape. Press a leaf or shell into the plasticine, then carefully remove it. You have just created a mould.
- 2 Put some plaster powder in a disposable cup and gradually mix in small amounts of water using the icy-pole stick until the mixture forms a thick paste. Pour the paste into your mould.
- 3 Leave the plaster to set.
- 4 Carefully remove the plaster and observe the cast you have made.

Analysis

- 1 How does the cast compare with the mould?
- 2 Did the process cause any distortions in the cast? Do you think this might happen in nature as a fossil forms?

Determining the age of fossils and rock layers

The age of a fossil can be determined using the order of rock layers in which it is found. We know that the oldest sedimentary layers are at the bottom and the youngest are at the top of the rock. This is called the **law of superposition**.

Putting fossils into an order from youngest to oldest is called **relative dating**. Relative dating does not require us to put a date on something. It is about the order in which events occur. The use of **radioactive elements** in minerals to put an actual date on an event is called **absolute dating**. Radioactive elements are part of mineral crystals in igneous rocks. Over time, the radioactive atoms disintegrate and change into other atoms. Scientists know this and can use this to work out how old a rock is (Figure 18.9.6).

law of superposition

a principle that states the oldest rock layers will be at the bottom and the youngest on top

relative dating

putting fossils, rocks or events into the order in which they occurred

radioactive element

an element that can produce radioactivity

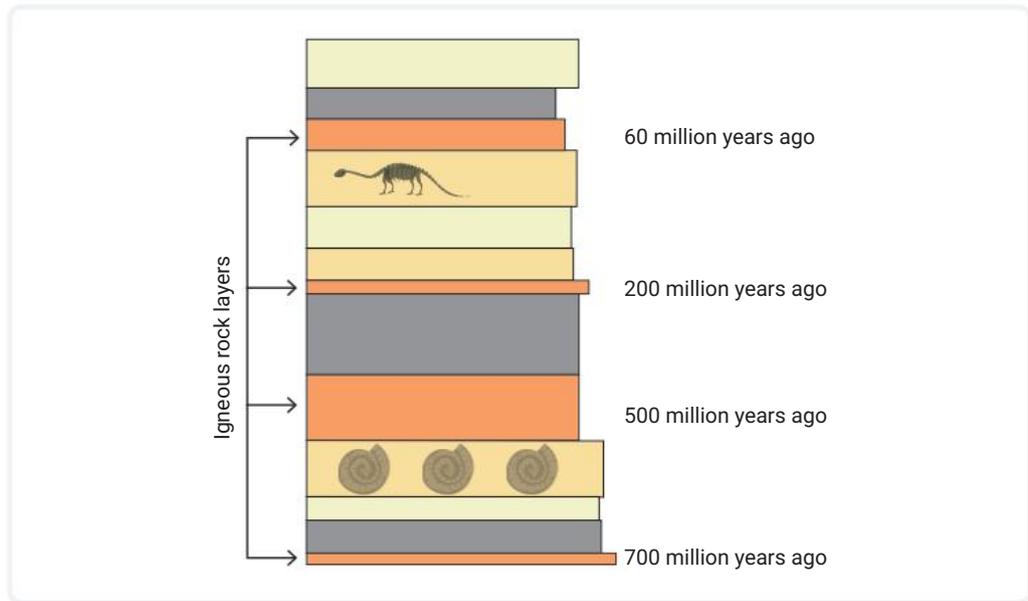
absolute dating

using scientific equipment to determine how old something is



Video activity
How do fossils form?

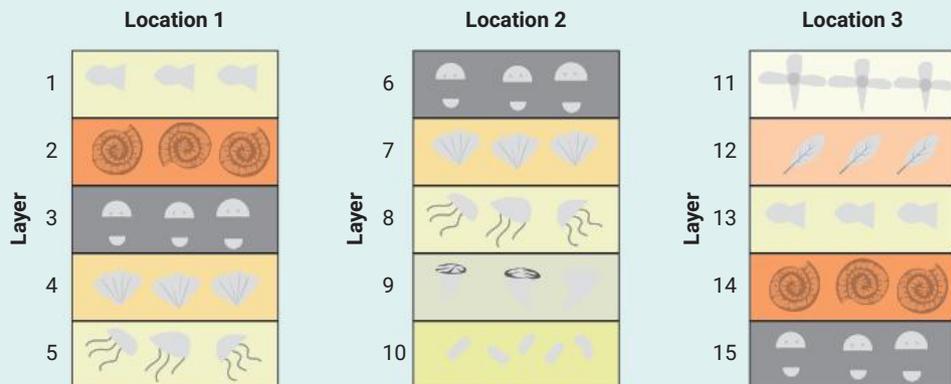
Interactive resource
Label: Fossil formation steps



▲ **FIGURE 18.9.6** Scientists can work out the relative age of a rock or fossil by looking at the order of rock layers. However, to find out the absolute age of a rock or fossil, scientists use the elements in minerals in igneous rocks.

18.9 LEARNING CHECK

- 1 What is a fossil?
- 2 **Define** the law of superposition.
- 3 In what types of rocks do fossils form?
- 4 What sorts of things can become a fossil?
- 5 The figure below shows layers of sedimentary rocks from three locations. Fossils found in the rocks are represented by different symbols.



- a Which is the oldest layer within the three locations?
 - b Draw the youngest fossil shown in the sections.
- 6 **Construct** a flow chart showing the stages in producing a fossil found in a rock.

18.10 Shaping rocks into tools

**IN THIS MODULE,
YOU WILL:**

- ✓ recognise that Aboriginal and Torres Strait Islander Peoples have long quarried and mined rocks and minerals
- ✓ examine how Aboriginal and Torres Strait Islander Peoples applied their traditional geological knowledge to select and process rocks for different purposes.

Obtaining rocks and minerals: quarrying and mining

Aboriginal and Torres Strait Islander Peoples have a deep understanding of the natural environment and its materials. They also have great knowledge and skills to design tools that are flexible, adaptable and sometimes very specific to a certain task. These factors are the key to why their technologies have been so successful over many years.

For many thousands of years, Aboriginal and Torres Strait Islander Peoples have been mining and quarrying the land for a variety of rock and ochre types. In the eastern states alone, there are several hundred recorded Aboriginal and Torres Strait Islander Peoples' rock and mineral extraction sites. At Wilgie Mia, in Western Australia, the Wajarri Yamatji Traditional Owners have mined ochre for an estimated 30 000 years, making it the world's oldest continuous mining operation.

Important!

Please remember never to touch or disturb Aboriginal and Torres Strait Islander Peoples' artefacts. Report any finds to your local cultural heritage authority.



▲ **FIGURE 18.10.1** Aboriginal Peoples' sandstone quarry on Mithaka Country, far western Queensland



▲ **FIGURE 18.10.2** Debris from silcrete quarry and tool making, Mithaka Country



◀ **FIGURE 18.10.3** (a) Evidence of reduced sandstone blank for the production of a grindstone, Mithaka Country; (b) completed grindstone, Mithaka country. Note peck marks from the shaping process.

The locations of valuable rock and mineral deposits were well known to Aboriginal and Torres Strait Islander Peoples and ownership of the mine or quarry rested with the cultural group on whose land it was located. Although most stone tools could be made from readily available local materials, highly specialised tools, such as those made from Mt William greenstone, basalt and natural glass, were highly prized and important for trade between groups.

☆ ACTIVITY 1

Discuss why Mt William greenstone axes have traditionally been found to be used by many different Aboriginal and Torres Strait Islander Peoples.

Manufacturing artefacts: from rocks to tools

Through observation and trial and error, Aboriginal and Torres Strait Islander Peoples developed a deep understanding of the properties of different rocks and minerals. They applied this understanding to make stone tools for different purposes, including food

processing, cutting, hunting, scraping and cleaning animal skins, and to make other tools. Ochre minerals were processed to produce pigments used for cosmetics, body and artefact decoration and visual representations (cultural paintings).

Aboriginal Peoples achieved two world firsts with stone technology. They were the first to produce ground edges on cutting tools and the first to grind seeds.

Chopping tools such as hatchets (a small axe attached to a handle) were used for a variety of reasons, including to fell trees, to remove sheets of bark for housing and canoes, to cut shields out of trees and to cut toe holds in trees for climbing. Hatchets needed to be made from strong, hard rock that did not fracture under high impact, and which could also be ground to produce a wedge with a sharp edge. The main type of rock used to make these chopping tools was igneous rock, such as fine-grained basalt.

Cutting and scraping tools – such as flake and scraper knives, spearheads and chisels – were made from rock that could be flaked to produce a sharp edge. Rock types commonly used were hard sedimentary rock such as chert and flint, and metamorphic rock such as quartzite.



▲ FIGURE 18.10.4 A selection of Aboriginal stone axes (origin unknown)



► FIGURE 18.10.5 Aboriginal stone knives (origin unknown) with spinifex resin handle



Aboriginal and Torres Strait Islander Peoples used pounding and grinding tools for processing food such as grinding seeds and nuts, or processing ochre. Usually, sedimentary rocks such as sandstone and metamorphic rocks such as quartzite and schist were used to manufacture grindstones (also called millstones by archaeologists) because the surface was more abrasive. Grindstones were often shaped to produce a large depression in the surface. Substances to be ground were placed in the depression and a round or an oval top stone (archaeologists call this a muller stone) was used to finely grind these substances.



▲ FIGURE 18.10.6 A Nardoo grindstone. The top stone is used for pounding and grinding Nardoo sporocarps (the fruit bodies of an aquatic fern), Mithaka Country.

Testing rocks for hardness and strength

☆ ACTIVITY 2

In this activity, you will test the hardness and strength (resistance to breaking or being deformed) of rock samples to determine the best type for making a hatchet.

You need

- samples of different types of rock (igneous, sedimentary and metamorphic)
- steel nail
- hammer
- hard surface such as a concrete path

⚠ Safety

Wear safety glasses and protective clothing to avoid being injured by flying pieces of rock. Hold the hammer firmly when hitting the rock to avoid it slipping from your grip.

What to do

- 1 Examine the rock samples provided and predict which would make the best hatchet head.
- 2 Construct a results table to record the type of rock, effect of scratching with a nail and effect of being hit with a hammer.
- 3 Using firm pressure, draw the sharp end of a nail over the surface of the rock sample. Record the results.
- 4 Repeat step 3 for all samples.
- 5 Place a rock sample on a hard surface (such as a concrete path) and firmly strike it with a hammer. If there is no effect, repeat until an effect is observed, to a maximum of four blows. Record the results.

What do you think?

- 1 **Analyse** the results and discuss which sample of rock would make the best hatchet head.
- 2 **Compare** this to your prediction. Explain why they match or don't match.
- 3 Was this a fair test? Explain your answer.



SCIENCE SKILLS IN FOCUS

IN THIS MODULE, YOU WILL FOCUS ON LEARNING AND IMPROVING THESE SKILLS:

- ▶ consulting with Aboriginal and Torres Strait Islander Peoples to conduct investigations on Country/Place.

Fieldwork allows you to learn more about the environment in which you live. It is important to make minimal changes to the environment while you are doing fieldwork, and to care for the land. One important aspect of caring for the environment is recognising Aboriginal and Torres Strait Islander Peoples' artefacts and heritage sites of significance, and ensuring you cause no harm to those sites, while showing respect for Country/Place.

Here are some things to consider in planning your fieldwork.

▶ Preparation prior to entering the field

- Whose Country/Place will you be visiting? Can you consult with Aboriginal and Torres Strait Islander Elders about your visit? How will you get in touch with Aboriginal and Torres Strait Islander Elders in your area? Have you asked an Aboriginal and Torres Strait Islander Elder if they would spend some time showing you the area?
- Questions to be asked of Aboriginal and Torres Strait Islander custodians:
 - Are there areas you need to avoid or be careful of when working on Country/Place in a particular way?
 - Are there any particular artefacts you might find on the field trip?
 - What should you do if you find an Aboriginal and Torres Strait Islander artefact on your trip?
 - Is there advice on any hazards you might encounter?

▶ Researching artefacts

- What do Aboriginal and Torres Strait Islander Peoples' stone artefacts look like? Sometimes, artefacts are made of rocks not found in your local area.
- Your local museum is likely to have online images of Aboriginal and Torres Strait Islander Peoples' artefacts. Make yourself familiar with the appearance of stone tools. You could also refer back to Module 18.10.

▶ Dealing with outcrops, artefacts and heritage sites encountered on the field trip

- Do not touch or disturb artefacts. How might you record what you find? Who will you tell about your find?
- Do not break rocks from outcrops. If samples are to be collected, only take small amounts and select loose samples on the ground. It is best to photograph, draw and describe rocks and outcrops while you are in the field.
- If you find a heritage site, leave it untouched and move away to another area in the Country/Place you are on. Let others know, so they can avoid the site too.
- If you encounter Aboriginal and Torres Strait Islander Peoples' artwork, do not touch it. This damages the artwork.
- Report any finds to your local cultural heritage authority. In New South Wales, this will often be your Local Aboriginal Land Council.

PLANNING TO CONDUCT FIELDWORK ON COUNTRY/PLACE

AIM

To prepare a guide for procedures to be followed when encountering Aboriginal and Torres Strait Islander artefacts and heritage sites on field trips

MATERIALS AND EQUIPMENT

- two or three other students to discuss ideas and information

PROCEDURE

- 1 Use the information in the Science skills in focus to make a list of points to include in the guide for your field trip. Start by identifying where you can find help from Aboriginal and Torres Strait Islander Peoples and the questions you wish to ask them.
- 2 With the assistance of your teacher, see whether an Aboriginal and Torres Strait Islander Elder or their delegate can answer your questions.
- 3 Research Aboriginal and Torres Strait Islander Peoples' stone tools and other artefacts you might encounter. Make drawings or descriptions to help you identify these products if you encounter them on your field trip.
- 4 Research commonwealth, state and territory cultural heritage laws that must be observed when working on Country/Place.

- 5 Use the information about laws, dealing with outcrops and artefacts to make a set of rules students should follow on the field trip. Write a reason for each rule.
- 6 Assemble your information into a one- or two-page handout as a reference for the field trip.

ANALYSIS

- 1 Why should we develop procedures to follow when we encounter Aboriginal and Torres Strait Islander Peoples' artefacts or heritage sites?
- 2 What did you learn during this investigation about the history of Aboriginal and Torres Strait Islander Peoples in your area?
- 3 How confident are you that you can identify artefacts, and that you will know what to do if you find them?

CONCLUSION

Have you made a useful guide to encountering artefacts and heritage sites on your field trip?

18.12 Dealing with acid mine water

BY THE END OF
THIS MODULE, YOU
WILL BE ABLE TO:

- ✓ explain why mines need to be carefully rehabilitated to prevent damage to creeks and waterways.



▲ FIGURE 18.12.1 The Rio Tinto River in Spain

Acid mine drainage

Figure 18.12.1 shows a river in Spain called the Rio Tinto. There is little life in the river and its colour comes from minerals dissolved in the acidic river water. How did the river come to be like this, and how can we prevent similar fates for our waterways?

Copper is an example of a valuable resource that we extract from the earth. The most commonly mined copper minerals are chalcopyrite (CuFeS_2) and chalcocite (Cu_2S). These are called sulfides because the metals are combined with the element sulfur. The Rio Tinto River drains an area where a huge amount of sulfide ore was located.

Acid mine drainage is an environmental problem. It is caused when sulfide minerals contact oxygen in the air. The minerals weather, producing compounds of sulfur and oxygen called sulfur oxides. When these oxides dissolve, they react with water and form acids. The acidic water will damage life in rivers and creeks if it escapes out of the mine. The acid mine water is also capable of dissolving elements such as copper, zinc, arsenic, cadmium and lead. These metals can end up in plants and animals and, over time, may cause illness and death.

Mine rehabilitation is the process undertaken by scientists and engineers to clean up a mining area. Mining can cause damage to the environment, so it is important to clean up or rehabilitate mining sites after they are closed. Mine clean-up is incredibly important to reduce the impact that mining has on the environment. For example, it involves treating any acidic water the mine has produced so that rivers are not polluted. The cost of treating acid mine drainage is high but the cost of damaging the environment is even higher.



Video activity
Cultural reconnection:
Mine rehabilitation

18.12 LEARNING CHECK

- 1 **Describe** the steps in which acidic, metal-rich mine water is produced.
- 2 **Explain** why drainage from acid mines should not be allowed to enter rivers or streams.
- 3 The Rio Tinto River receives water from areas that have been mined for 5000 years. In previous times, why did the miners not take steps to prevent the discharge of acid mine waters?

18 REVIEW

REMEMBERING

- 1 **Identify** the features/properties of a mineral.
- 2 What term is used for the following mineral properties?
 - a How easily it scratches
 - b Splitting along flat surfaces
 - c The way a surface reflects light
 - d The colour of powdered mineral
- 3 **State** an example of each of the following rock types.
 - a An igneous extrusive rock
 - b A volcanic glass
 - c A sedimentary rock made up of clay particles
 - d A contact metamorphic rock
 - e A regional metamorphic rock
- 4 Copy and **complete** the table at the bottom of this page by placing a tick for each rock type with the property listed.
- 5 **Identify** whether the following sentences are true or false. If the statement is false, **rewrite** the sentence to make it true.
 - a Minerals are composed of two or more chemical elements.
 - b Granite is an example of an intrusive rock.

- c Weathering is the chemical breakdown of minerals.
- d Heat and pressure are the causes of metamorphic change.
- e Absolute dating provides an age for something in numbers of years.
- f Trace fossil is the name given to the preserved soft parts of an animal or plant.

UNDERSTANDING

- 6 **Explain** why sediments at the start of a river are different from those found where the river enters the ocean.
- 7 **List** the properties you would look for to distinguish metamorphic rocks from igneous rocks.
- 8 Why is a shellfish more likely to become a fossil than a jellyfish?
- 9 What process will turn a metamorphic rock into magma?

APPLYING

- 10 **Explain** the difference between a mineral and a rock.
- 11 **Explain** why sand blown from a beach into sand dunes has a finer grain size than the sand on the beach.

Property	Rock type		
	Igneous	Sedimentary	Metamorphic
Composed of interlocking mineral crystals			
May contain large crystals			
Has a texture called foliation			
May contain gas bubbles			
Contains fragments and particles cemented together			
May contain fossils			

- 12** Volcanic ash is composed of shiny, sharp fragments of volcanic glass. What does this tell you about the cooling of the magma that formed the ash?
- 13** Use your understanding of the rock cycle to **create** a flow chart showing how a sediment can become a metamorphic rock such as slate.
- 14** **Justify** why an animal sinking into a swamp is more likely to be fossilised than the same animal sinking into a river.
- 15** **Describe** the properties of a sediment that would help you identify whether it had been transported a long way from where it was eroded.
- 16** Why can a metamorphic rock have bedding and foliation but a sedimentary rock can only show bedding?
- 17 a** **Identify** one type of stone tool constructed and used by Aboriginal or Torres Strait Islander Peoples.
- b** **Describe** the properties of rock required for this tool and **explain** how these relate to the use of the tool.
- c** **Name** one type of rock used in constructing this tool.

EVALUATING

- 18** What features would help you distinguish between a cast fossil and a mould fossil?
- 19** Light-coloured minerals such as quartz and feldspar are more common in beach sand than dark-coloured minerals such as pyroxene and olivine.
- a** What does this suggest about the differences in properties of the light- and dark-coloured minerals?
- b** **Explain** why beaches on the volcanic island of Hawai'i contain lots of dark minerals such as olivine.

- 20** If you dig a deep hole in soil, the soil becomes harder and harder to dig out of the hole. Why does the soil become harder to dig and what would have to happen to turn the soil into a rock?
- 21** **Explain** how pressure and temperature lead to the characteristics, features or properties of regional metamorphic rocks.
- 22** **Explain** why diamond and graphite, both composed of carbon, are classified as different minerals.
- 23** The table at the bottom of this page contains a list of properties for five different minerals. Use it to answer these questions.
- a** Which mineral will be broken down most quickly in a swiftly flowing river?
- b** Which properties would be the best ones for distinguishing olivine and biotite from the other minerals?
- 24** Basalt weathers to form clay-rich and fertile soils. Granite weathers to form sandy, low-fertility soils. **Explain** why these igneous rocks give rise to such different soils.

CREATING

- 25** **Create** a concept map of the key terms in this chapter. Make links between the terms and **label** the links to show what the relationships are.

Mineral	Colour	Hardness	Cleavage	Lustre	Density (g/cm ³)
Olivine	Green-brown	6.5	None	Glassy	3.2–3.4
Orthoclase	White, pink, light green, brown	6	2 at 90°	Glassy	2.6
Quartz	Colourless or a wide range of colours	7	None	Glassy	2.6–2.7
Biotite	Black to dark brown	2.5–3	1	Pearly	2.8–3.4
Calcite	Colourless or a wide range of colours	3	3	Glassy to pearly	2.7

SCIENCE IN DEPTH STUDY

#18

1 Connect what you've learned

In this chapter, you've learned about the characteristics, properties and features of different types of rocks and the processes that change them. Examine the image on this page carefully and make a list of hypotheses about the possible rock types and processes operating on Mars.

2 Check your thinking

The rock at the front of the picture seems to contain holes. It might be a volcanic rock with gas bubbles. It might be a sedimentary rock with parts that have weathered and eroded away. What features of the rock would you look for to decide what type of rock it is?

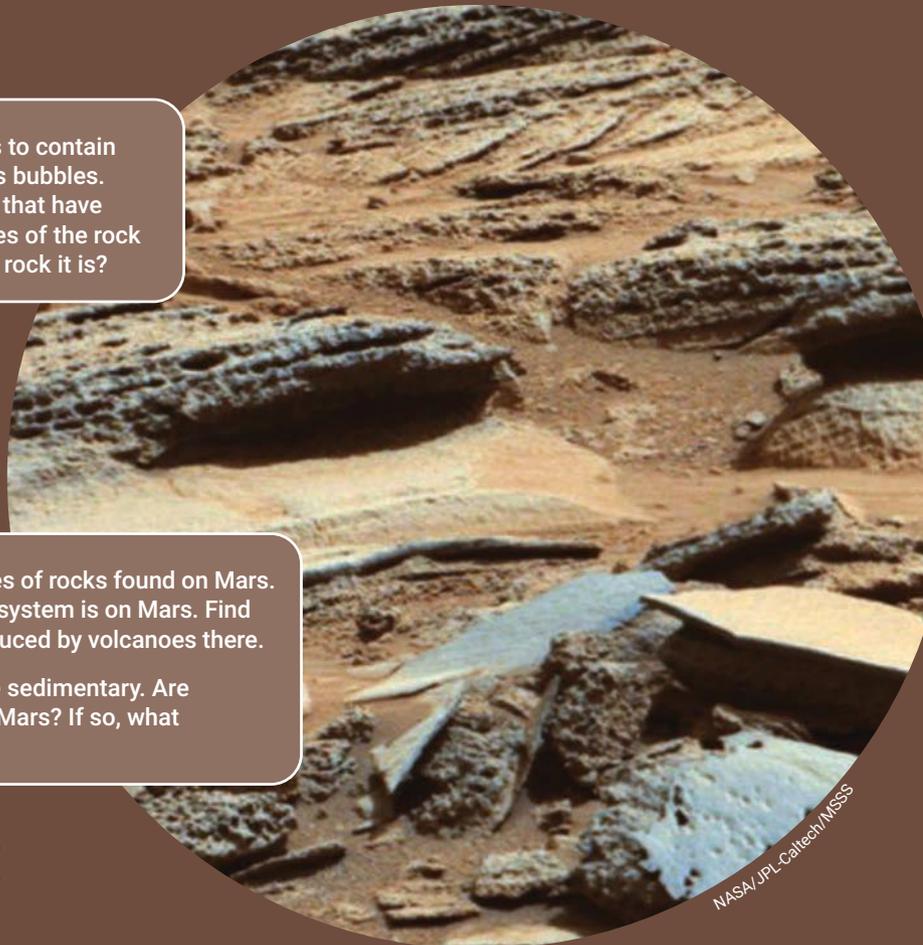
3 Get into action

Make a plan to research the types of rocks found on Mars. The largest volcano in our solar system is on Mars. Find out what types of rocks are produced by volcanoes there.

Rocks in the image appear to be sedimentary. Are sedimentary rocks common on Mars? If so, what transported the sediment?

4 Communicate

Create a modified diagram of the rock cycle for Mars. Include the rock types and processes you have inferred or researched.



Glossary

A

abiotic factor a non-living component of an ecosystem

absolute dating using scientific equipment to determine how old something is

acceleration due to gravity the rate at which a falling object gets faster due to the force of gravity

accuracy how close a measurement is to the correct value

adaptation a change over generations that makes a species more suited to surviving and reproducing in a particular environment

aerosol a type of colloid in which a solid or a liquid is mixed in a gas

agar plate a transparent dish with lid containing a jelly-like substance called agar, used for growing bacteria or fungus in the laboratory

aim a statement that states the purpose of the investigation

air quality index (AQI) a measure of the level of pollution in the air, expressed as a number from 0 (no pollution) to 500 (maximum pollution)

air resistance friction caused by an object's motion through the air

alkali earth metals group 2 metals on the periodic table; they are quite reactive

alkali metals group 1 metals on the periodic table; they are highly reactive

alpha particle a helium nucleus (two protons and two neutrons) emitted when unstable larger nuclei decay

alveoli air sacs at the ends of the bronchioles in the lungs (singular: alveolus)

amylase the enzyme that digests carbohydrates

analogy a comparison

analysis the careful study of data to look for patterns and trends

anomaly something that deviates from the standard

anus the external opening of the rectum, through which faeces leave the body

aorta a large artery in humans that takes blood from the left side of the heart to the body

apex predator the organism at the top of a food chain

apparatus equipment designed or set up together for a particular use

appendix a small tube-shaped sac attached to, and opening into, the lower end of the large intestine

applied force a force that is applied to an object by another object

aqueous describes a solution that is a substance dissolved in water

artefact an object made by a human being

artery a blood vessel in humans that carries blood away from the heart

asthenosphere the solid part of the mantle below the lithosphere (which can flow)

astronomical unit the average distance from the centre of Earth to the centre of the Sun, equivalent to 149.6 million kilometres (abbreviation AU)

astronomy the study of objects beyond Earth, including stars, other planets and galaxies

atmosphere the gaseous layer surrounding Earth

atom the smallest part of an element that gives the element its chemical properties

atomic number the number of protons found in the nucleus of an atom

atomic weight the mass of one atom of an element, measured in atomic mass units

atria the two upper chambers in the human heart, which receive blood from veins (singular: atrium)

attractive force an indirect force that brings two objects closer together

autoclave a machine that uses steam at very high pressure to kill microorganisms on instruments and equipment

autotroph an organism that can make its own food

axis an imaginary line that an object spins around

axon the part of a neuron that carries the nerve impulse

B

balanced force a force that has an equal force acting on the same object in the opposite direction

batholith a very large volume of intrusive rock, formed deep under Earth's surface by solidification of magma

bed a horizontal layer of sedimentary rock

behavioural adaptation a change to how a species behaves in response to its environment

bias a strong preference for one thing or idea over another

biconcave shaped like a flattened disc with dips on both sides

big data large, complex datasets that are difficult to process and analyse

binomial nomenclature a two-word naming system for naming living things

biodegradable describes a substance or product that is able to completely break down and return to natural products within a short time

biodiversity the variety of living species on Earth, including plants, animals, bacteria and fungi

biological control the reduction of a pest species by using natural enemies

biological weathering a process of weathering in which living organisms break down rocks

biology the study of living things

biomass the mass of living organisms

biomass pyramid a graphical representation of the total biomass present at each trophic level of an ecosystem

biosphere the parts of Earth where life is found

biotic factor a living component of an ecosystem

blue flame the hottest flame from a Bunsen burner

body fossil a fossil formed from the remains of a plant or an animal

boiling the process of changing from a liquid to a gas at the boiling point

boiling point the temperature at which all of a substance changes from a liquid to a gas

bolus a ball of food that passes into the oesophagus from the mouth

bowel motion the process of egesting faeces through the anus

breed a group of organisms of the same species with distinctive features

bronchi tubes that branch off the trachea to the left and right lung (singular: bronchus)

bronchiole a smaller tube connected to the bronchi where they divide

buoyancy the upward force exerted by a liquid on an object

buoyant force the upwards force acting on objects in a liquid



caecum a pouch or large tube-like structure at the beginning of the large intestine; receives undigested food material from the small intestine

calorie (cal) the imperial (non-metric) unit of measurement for energy

canopy the 'top' of a forest, made up of overlapping leaves and branches of tall trees

capillary a very small blood vessel in humans, located in between the smallest arteries and smallest veins

carbohydrates a complex food group found in starchy foods such as bread and rice

carnivore an organism that feeds solely on animals; a meat-eater

carnivorous describes an organism that feeds on animals only

cartilage flexible tissue that makes up part of the skeleton

case study an in-depth analysis of an issue or situation

cast a fossil formed when minerals fill a fossil mould

cathode ray a beam of electrons produced by a cathode ray tube

causation a relationship in which a change in one variable causes a change in another variable; one event is the result of the occurrence of the other event

cell the basic structural unit of all living things

cell membrane the thin layer that forms the outer boundary of a living cell

cell theory the basic theory in modern cell biology that states that all living things are made up of cells, cells are the basic units of all living things, and cells form from existing cells

cell wall the rigid outer covering of plant cells that surrounds the cell membrane

cellular respiration a series of chemical reactions that break down glucose and release chemical energy

cementation the process whereby new minerals bind sediment grains together

centrifuge a machine that spins very fast and separates heavier substances from lighter substances

centrifuging the process of using a centrifuge to separate a mixture

centriole a tube-like structure found near the nucleus in animal cells that is involved in cell division

chamber one of the compartments that form the structure of the heart; there are four chambers in the human heart

characteristic a quality or feature that makes something recognisable

chemical bond a force that holds atoms together

chemical change when the chemical make-up of a substance changes, and a new substance or substances are formed

chemical digestion the chemical breakdown of complex compounds into simpler compounds

chemical equation a symbol summary that shows the reactants and products of a chemical reaction

chemical formula a collection of symbols and numbers that represent the number of atoms in a molecule or compound

chemical potential energy energy stored in the chemical bonds of a substance and released when the substance reacts

chemical property a property of a substance that shows how it reacts when combined with other substances

chemical reaction a process that occurs when a substance changes to produce a new substance

chemical symbol a letter or letters of the Latin alphabet used to represent an atom of a specific element

chemical weathering a process of weathering that changes the chemical composition of the minerals in rocks

chemistry the study of the composition and properties of matter

chlorophyll the green pigment in chloroplasts that absorbs light energy for photosynthesis

chloroplast an organelle in plant cells that contains chlorophyll and carries out photosynthesis

cholesterol an insoluble, waxy substance

chromatography a process used to separate mixtures on the basis of their solubility

chyme partially digested food that passes from the stomach to the small intestine

cite to reference or give credit to a secondary source of data or information

classification grouping things according to how similar they are

clastic a rock composed of rock or mineral fragments

cleavage the way a mineral splits to produce a flat surface

climate change denial theories that deny humans are causing climate change

closed system a system that does not allow transfer of matter in or out of the system

cluster a group of data points that are closer to each other than to other data points in a dataset

coarse focus knob a knob that adjusts a microscope so that it focuses on the specimen by rapidly raising and lowering the stage

collaborative work work carried out by many people by sharing ideas and knowledge

colloid a mixture of two or more insoluble substances that remains evenly mixed and does not settle over time

column a vertical division in a table

community all the organisms that live together and interact

compaction the process whereby pressure forces particles closer together

companion cell in plants, a cell adjacent to a sieve tube cell that makes substances the sieve tube cell cannot make

compound a pure substance whose particles are made up of two or more different atoms chemically bonded together

compress to squash something so it takes up less space

compressibility the ability to be compressed (or squashed)

concentrated having a large amount of solute in a certain volume of solution

concentration the amount of solute present in a specified amount of solution

conceptual model a mental representation of a concept or idea; also called a mental model

conclusion a judgement reached by reasoning

condensation the process of changing from a gas to a liquid

condenser the piece of equipment in a distillation apparatus that cools the gas so that it changes to liquid

conditions factors that affect a chemical reaction, such as heat or pressure

conduction the transfer of heat through substances by direct contact, usually solid objects

conductor an object that allows heat to transfer easily

consecutive following one another in order

consequence the result of a decision or action

consumer an organism that must consume its food; an animal; a heterotroph

contact metamorphism rock metamorphism caused by heat

continental drift the movement of the continents across the surface of Earth over geological time

continental plate a lithospheric tectonic plate containing a lot of continental crust

continuous data data from measurements that may include whole numbers and any value between them

control test a test in an investigation in which nothing is changed; often just called the control

controlled variable a factor that needs to be kept the same throughout a scientific investigation so that it does not influence the result

convection the transfer of heat within fluids

convergent boundary the border at which crust is destroyed as one plate moves beneath another, or where two continental plates collide

cookies files of text stored on your computer and shared with websites when you revisit them

corona the bright outer atmosphere of the Sun

correlation a trend in data in which one variable changes consistently as the other variable changes

crescent a phase of the Moon when only a small arc-shaped section of the Moon is visible from Earth

crust the outermost and thinnest layer of Earth

crystal a solid in which the atoms are arranged in a well-ordered pattern

crystallisation the process in which excess solute in a solution forms crystals

cuticle the waxy protective layer on the surface of a plant

cycle a continuous, connected and repeated process

cytoplasm a jelly-like substance that fills the inside of a cell

D

data the numbers or observations collected during an experiment; information gathered for a scientific inquiry

data cleaning the process of fixing errors and other problems in datasets

data scientists people who use scientific skills to analyse and interpret complex digital data

dataset a collection of related data

daughter cells two cells that result from the division of a parent cell

day the time it takes for a planet to make one rotation around its axis

daytime the time of day between sunrise and sunset

decantation the process of decanting

decanting pouring off the top, less-dense liquid

decomposer an organism, such as a fungus or bacteria, that breaks down dead matter

deflect experience a change in direction due to a force

deforestation the removal of naturally occurring forest by logging or burning

density the mass per unit volume of an object

dependent variable the factor that may be affected by the independent variable; the factor that can be measured or counted

deposition (in chemistry) the process of changing from a gas to a solid

deposition (in earth science) the laying down of sediment

depth study a major research project on a topic of interest and using linked research

detritivore an organism that feeds on dead or decaying matter

diagnosis the identification of the nature of an illness

diaphragm a sheet of muscle under the lungs that assists with inhalation and exhalation

diatomic describes a molecule consisting of two atoms (*di* means 'two'; *atomic* means 'atom')

dichotomous key a tool used by scientists to classify objects (often living things); two choices are given at each level, until there is only one type of living thing in each final group

differentiation a biological process whereby cells of an organism become specialised

diffusion the movement of particles from an area of high concentration to an area of low concentration

digital footprint the body of data a person creates through their actions online

digital system machines with digital electronics and software that generate or store data

dilute having a small amount of solute in a certain volume of solution

direct force a force applied by one object to another object when they are touching each other

discrete data data where there is only a limited number of possible values

disease an illness that affects the normal functioning of an organ or system

disorder a group of symptoms that is usually related to a disease

dissolve when a substance is mixed with another and the particles from both substances spread out evenly until they are too small to see

distillate the liquid collected during the distillation process

distillation a process used to separate solutions that collects both the solute and the solvent

divergent boundary the border at which new crust is formed as tectonic plates pull away from each other

domesticated adapted over generations to live with humans

ductile able to be stretched into a wire

E

earthquake a violent shaking of the ground caused by energy-carrying waves

eclipse when light from the Sun is blocked by another object

ecliptic the path travelled by the Sun and planets as seen from Earth

ecosystem the living and non-living factors of an environment and all their interactions

egest to pass out of the body

elastic potential energy energy stored in a spring or elastic material

electrical energy energy carried by charged particles in electric circuits

electron configuration the arrangement of electrons in electron shells in an atom

electron a negatively charged particle that moves in space around the nucleus of an atom

electrostatic force a force acting between two or more electrically charged objects

element a pure substance made up of only one type of atom; it cannot be broken down into a simpler substance

ellipse a regular oval shape

emulsion a type of colloid in which a liquid is mixed in another liquid

endangered in danger of becoming extinct

endoplasmic reticulum *see* rough endoplasmic reticulum; smooth endoplasmic reticulum

endoscope an instrument used to look inside the human body

endothermic reaction a chemical reaction that takes in heat energy

energy the ability to do work, such as moving or cooking, or the potential to do work, such as the chemical potential energy stored in food

energy pyramid a graphical representation of the total energy present at each trophic level of an ecosystem

energy transfer the movement of a single type of energy from one place to another or from one body to another

energy transformation the changing of one type of energy into another type of energy

environment a unique set of non-living and living factors for a particular area and time

environmental science the study of the conditions of the environment and their effects on all organisms

enzyme a protein found in the body that speeds up a chemical reaction

ephemeral a plant that completes its life cycle quickly and spreads large quantities of seeds

epicentre the point on Earth's surface directly above an earthquake focus

epidermis the cellular surface layer of a plant

equipment tools used to perform a task

erosion the movement of weathered material away from where it forms by water, wind, ice or gravity

estuary an area where a freshwater river meets the ocean

ethical morally right, fair

eukaryote an organism composed of one or more cells that contain a nucleus and membrane-bound structures

evaporating basin a small porcelain dish used to evaporate solvent from a solution

evaporation the process of changing from a liquid to a gas at a temperature lower than the boiling point

evolved changed slowly over many generations

excretion the process of eliminating or expelling waste matter

exothermic reaction a chemical reaction that releases heat energy

expiration breathing out

extinct no longer in existence

extrapolation the estimation of an unknown value by extending a trend beyond the known values

extrusive describes an igneous rock formed from lava at or above the surface of Earth

eyepiece lens a lens on a microscope through which the eye views the image formed by the objective lens

F

faeces undigested waste material

fair test an investigation that is conducted correctly to answer a scientific question

fault a fracture on Earth's surface where rocks have moved due to tension or compression forces

fats a complex food group found in foods such as butter and cream

fertile able to produce offspring

fibre the indigestible parts of plants

fibrous roots many small roots of similar size that grow from the bottom of the stem of some plants

field a region of space in which an indirect force exists

field of view the diameter of the circular area that appears when you look into a microscope

filter funnel a funnel used to hold filter paper during filtration

filter paper paper with very fine holes (pores) that allow only very small particles to pass through

filtering performing the process of filtration

filtrate the substance that passes through the filter paper, usually a liquid

filtration (in biology) the process in the kidney where all materials, except for protein and blood cells, are forced out of the bloodstream

filtration (in chemistry) a process used to remove solid substances from a liquid or gaseous mixture based on differences in the size of particles

fine focus knob a knob that adjusts a microscope so that it focuses on the specimen by slowly raising and lowering the stage

fissure a long fracture or crack from which lava erupts

flocculant a chemical added to a colloid to make the particles clump together

flocculation the process in which particles in a colloid join to form larger clumps

flow move from one place to another in a steady stream

fluid a substance that can flow; a liquid or gas

foam a type of colloid in which a gas is mixed in a liquid

focus the place where earthquake energy is released

foliation layering in a rock formed by crystal regrowth

food chain a single linear diagram that shows the way energy and matter are transferred from producer to consumers

food web a group of interlinked food chains that gives an overall picture of how energy and matter are transferred through an ecosystem

force a push, pull, twist or squeeze experienced by an object when it interacts with another object

force arrow an arrow drawn on a diagram to illustrate the direction and relative strength of a force

force of attraction a force that pulls objects together

fossil the remains or traces of living organisms, preserved in rock

freezing the process of changing from a liquid to a solid

friction a force that acts against the direction of motion, or intended motion, of an object because of an interaction between its surface and another surface

fulcrum the point at which a lever is supported and rotates

full moon a phase of the Moon when the whole lit face of the Moon is visible from Earth

G

gas a state of matter in which the particles are very far apart and move with a lot of energy

gel a type of colloid in which a solid is mixed in a liquid

genetic material the information inside a cell that contains instructions for the development, maintenance and reproduction of living things

geocentric centred on Earth

geology the study of the liquid and solid parts of Earth

geosphere the solid part of Earth

geothermal energy heat that is trapped in rocks close to heat sources deep within Earth's crust

gibbous a phase of the Moon when more than half of the illuminated face of the Moon is visible from Earth

Golgi body an organelle that processes, packages and stores proteins and lipids

gravitational force a force acting between two or more objects as a result of their mass

gravitational potential energy energy associated with the position of an object above a reference height

gravity a force applied by one mass on another mass

greenhouse gases heat-trapping gases, such as carbon dioxide, that have been linked to global warming

group a vertical column on the periodic table

guard cells paired cells that surround the stomata of a plant, allowing them to open and close

H

haemoglobin the component of red blood cells that binds with oxygen

halogen an element in group 17 on the periodic table

hard parts refers to the hard parts of an organism's body, such as shells, bones and teeth

hazard something that has the potential to harm

heartburn a burning feeling in the oesophagus caused by rising stomach acid

heat thermal energy that is being transferred between different places or particles

heliocentric centred on the Sun

herbivore an organism that feeds solely on plants; a primary consumer

herbivorous describes an organism that feeds on plants only

heterotroph an organism that cannot make its own food and so gains nutrition by ingesting other sources

hierarchical in order of importance

high tide when the tide reaches its maximum level

hormone a chemical messenger

hotspot an unusually hot area in Earth's upper mantle where the mantle melts

hybrid the offspring of a mating between two different species

hydrochloric acid a type of acid; in the stomach it helps to digest food

hydroelectricity electrical energy produced by transforming gravitational energy of falling water into kinetic energy to drive a turbine

hydrosphere all the water on Earth

hydrothermal metamorphism rock metamorphism caused by hot fluids underground changing the chemical composition of rocks they pass through

hypothesis a testable explanation for something based on existing knowledge; a testable statement of the predicted relationship between the independent and dependent variables

I

igneous rocks rocks formed when molten materials (magma or lava) cool and solidify

immiscible describes liquids that are unable to mix; they separate into layers if combined

immune system a complex system that defends the human body against infection and disease

inclined plane a sloping ramp

independent variable the factor that you choose to vary in your investigation

indirect force a force that an object exerts on another object without the objects touching each other

inference a reasonable conclusion based on observations

infinite endless, without limits

information facts about an object, event or process

ingested taken in; eaten

inherit acquire traits from the genetic material passed down from parents

inner core the innermost, solid, metal part of Earth

inorganic a substance not formed from the remains or products of living things

insoluble unable to dissolve in another substance

inspiration breathing in

insulator an object that does not transfer heat well

interaction an action that occurs as two objects have an effect on each other

interdisciplinary involving knowledge from different branches of science

interpolation the estimation of an unknown value within the range of known data for a relationship

introduced species a species that was not part of the original ecosystem; for example, plants, animals and micro-organisms brought into Australia from other countries

intrusive describes an igneous rock formed from magma below the surface of Earth

intuition to know something without needing to think about it or study it

invasive species an introduced species that disrupts the ecosystem

ionic compound a compound formed when a metal and a non-metal chemically bond

iris diaphragm a part of a microscope that regulates the amount of light that strikes the specimen

isolated system a system in which no energy or matter is exchanged with the surroundings

J

joule (J) the metric unit of measurement for energy

K

kidneys the excretory organs of mammals

kinetic energy the energy of an object due to its motion

L

lava hot, molten rock that is expelled during a volcanic eruption

law a description of what happens in a phenomenon

law of conservation of energy a law of physics that states that energy cannot be created or destroyed

law of superposition a principle that states the oldest rock layers will be at the bottom and the youngest on top

length the distance between two points, measured in metres (m), centimetres (cm) or millimetres (mm)

lever a solid plank or bar that rotates about a point

light microscope a microscope that uses light to view the specimen

lignin a material that stiffens and strengthens plant cell walls

lignotuber a partly underground swelling of the trunk of a plant, with many buds that sprout after fire

likelihood the chance something will happen

line of best fit the line that best represents the trend of a set of data points

linked key (tabular key) a descriptive dichotomous key made of numbered questions or statements

Linnaean classification system a classification system consisting of a hierarchy of groups, with each group being further divided into smaller groups based on similar characteristics

liquefaction the process of changing into a liquid

liquid a state of matter in which the particles are close together but unable to break free of each other

lithification the process whereby a sediment under compaction becomes a rock

lithosphere Earth's crust and the rock-like upper part of the mantle

living things all organisms that are alive or were alive

low tide when the tide reaches its lowest level

luminous bright, giving off light

lunar eclipse when Earth blocks the Sun's light from reaching the Moon

lustre how shiny a metal is

lustrous shiny when cut or polished

lysosome an organelle found in animal cells that breaks down and recycles old, worn-out cell organelles

M

magma extremely hot liquid or semi-liquid rock formed under the surface of Earth

magnet a material that produces a magnetic field

magnetic force a force acting between two or more magnetic poles

magnetic reversal a change in the direction of Earth's magnetic field

magnetism a force that is experienced by metals such as iron

magnification the action of enlarging the apparent size of a specimen being observed

magnify to make something appear larger

malleable able to be beaten into different shapes

mantle the rock layer between the crust and the core of Earth

mass the amount of matter in an object, measured in kilograms (kg), grams (g) or milligrams (mg)

mathematical model a model that uses mathematical concepts to describe and predict the behaviour of objects or systems

matter anything that takes up space and has mass

mean the calculated 'central' value of a set of numbers; an average

mechanical advantage a measure of the force multiplication provided by a machine

mechanical digestion the physical breakdown of food into smaller pieces

median the middle of an ordered set of numbers

melting the process of changing from a solid to a liquid

melting point the temperature at which a substance changes from a solid to a liquid

membrane the thin layer that forms the outer boundary of a living cell, or of an internal cell compartment

meniscus the curved surface of a liquid when it is in a thin tube

metal a chemical element that has certain properties, such as conducting heat and electricity, being malleable and being ductile

metalloid a chemical element that has properties in between those of a metal and a non-metal

metamorphic rocks rocks that have been altered by heat, pressure or hot fluids

meteorologist a scientist who studies the atmosphere, weather and climate

method the steps that were taken during a scientific investigation; written in past tense

micrograph a photograph taken using a microscope

micrometre (μm) a unit of measurement equivalent to one-thousandth of a millimetre, or one-millionth of a metre

micro-organism a very small living thing, only visible with a microscope

mid-ocean ridge a broad, high, underwater mountain range in the ocean at a divergent plate boundary

mineral a naturally occurring inorganic solid with a neatly ordered crystal structure and characteristic composition

mitochondrion an organelle that generates chemical energy using cellular respiration

mixture a substance made up of different types of particles that are physically combined

mnemonic a memory aid that uses the pattern of letters in words

model a simplified representation of a process or object

Mohs scale of hardness a scale used to measure the relative hardness and resistance to scratching between minerals

molecular compound a compound formed when two different non-metals chemically bond

molecule two or more non-metal atoms bonded together

molecule of a compound a molecule in which two or more atoms of different non-metal elements are chemically bonded together; also known as a molecular compound

molecule of an element a molecule in which two or more atoms of the same non-metal element are chemically bonded together

monatomic/monoatomic an element consisting of just one atom (*mono* means 'one'; *atomic* means 'atom')

moon a natural satellite of a planet

motion the change in position of an object over time

mould a fossil made in the shape of a plant or an animal's remains after those remains have dissolved

multicellular composed of many cells



nanometre (nm) a unit of measurement equivalent to one billionth of a metre

native species an organism that originated and developed in the environment

navigate find the way; travel in the correct direction

neap tide a tide where the difference between high tide and low tide is small

negative correlation a correlation where one variable decreases as the other variable increases

nephron the structure in the human kidney where filtration of the blood occurs

network a group of interconnected people or things

neuron a nerve cell

neutron a particle in the nucleus of an atom that does not have an electrical charge

new moon a phase of the Moon when the part of the Moon facing Earth is in darkness

newton the unit of force (N)

night-time the time of day between sunset and sunrise

noble gases an element in group 18 on the periodic table

non-living things all the things that were never alive

non-metal a chemical element that has certain properties, such as being brittle, having a non-shiny appearance and low melting point

non-numerical information or a quality that isn't a number

non-renewable energy source a source of energy that is finite in nature; i.e. used at a faster rate than it can be produced

nucleus (in biology) the part of a cell that contains genetic material and is bound by the nuclear membrane

nucleus (in physics) the dense centre of an atom; positively charged

numbers pyramid a graphical representation of the total number of organisms at each trophic level of an ecosystem



objective not influenced by personal feelings or opinions

objective lens a lens on a microscope that receives light rays from the specimen and forms an image on the eyepiece

observation data collected through the senses (sight, smell, taste, touch or hearing) or with measuring tools

oceanic plate a lithospheric tectonic plate that contains mainly oceanic crust

omnivore an organism that eats both plants and animals

omnivorous describes an organism that feeds on both plants and animals

opaque cannot be seen through

open system a system that allows the transfer of matter in and out of the system

orbit the regular, repeating path an object takes in space around another object

orbital plane a surface that contains the orbit of a body

organ a collection of different tissues that combine to perform a specific function

organelle a specialised structure in the cytoplasm of a cell that has a specific function

organic relating to, or made from, living material

organism a living thing

orientate align with or direct towards

outer core the liquid part of Earth's metallic core

outlier a value that differs significantly from other values in a dataset



Pangaea a supercontinent that once existed on Earth; the name means 'all lands'

parallax error an error in the reading of an instrument due to the viewing angle

parent cell the original cell that divides to form two daughter cells

partial lunar eclipse when part of the light from the Sun reaching the Moon is blocked by Earth; only a portion of the Moon is visible from Earth

partial solar eclipse when the Moon's shadow stops a portion of the Sun's rays reaching Earth; only a portion of the Sun is visible from Earth

particle a tiny unit of matter

particle theory of matter a theory that states that all matter is made up of particles that are in constant motion

pattern data that repeats in a predictable manner

peer review evaluation of scientific work by other experts to assess validity and quality

penumbra the outermost part of a shadow where only some of the light is blocked by an object

period (in chemistry) a horizontal row on the periodic table

period (in space science) the time it takes for a satellite to complete one orbit or revolution

periodic table a method of arranging elements by increasing atomic number

peristalsis a progressive wave of contraction and relaxation along the digestive tract

phase change a change in the state of matter; an example of a physical change

phenomenon something that is observed to exist or occur (plural: phenomena)

philosopher a person who studies or writes about the truths related to knowledge

phloem plant tissue that transports sucrose from the leaves to the rest of the plant

photosynthesis the process by which plants use light energy from the Sun to produce simple sugars (e.g. glucose) in a series of chemical reactions

physical change a change in a substance that does not involve the production of a new substance; can usually be reversed

physical model a model constructed from physical materials

physical property a property of a substance that can be observed or examined without changing the composition of the substance

physical weathering a process of weathering that breaks rocks apart or wears them down, but does not change their chemical composition

physics the study of matter, energy and the interaction between them

physiological adaptation a change to a species' organs, cells or cellular processes that makes it better suited to its environment

phytoplankton microscopic algae; a producer that can support a large biomass of primary consumers

planet a natural body that orbits a star

planetary atomic model a model of the atom showing electrons orbiting the nucleus

plasma (in biology) the watery component of human blood, in which blood cells are suspended

plasma (in physics) electrically charged gas abundant in stars; often called the fourth state of matter

platelets fragments of cells that act in blood clotting

pollutant a substance introduced into an environment that can be harmful

population the organisms of one species that live together in an area

portfolio of work an ordered record of ideas, notes, data and sources about the preparation, carrying out and analysis of a depth study

positive correlation a correlation where one variable increases as the other variable increases

potential energy energy that is stored, ready to be changed to another type of energy

precipitate a solid substance formed in a solution as a result of a chemical reaction

prediction the expected results

primary consumer (first-order consumer) an organism that eats a producer; a herbivore or omnivore

primary data data collected by you; also called 'first-hand' data

privacy the right to be free from public attention

procedure a set of instructions to follow; written in the present tense

producer an organism that produces its own food; usually a plant; an autotroph

product a new substance produced in a chemical reaction

prokaryote a unicellular organism without a nucleus

property a characteristic or feature of a substance

proteins a complex food group found in foods such as meat, fish, soybeans and cheese

proton a positively charged particle in the nucleus of an atom

pseudoscience ideas or practices that claim to be scientific but do not have scientific evidence to back them

pulley a wheel on an axle that enables a change in direction of a rope or cable

pulling force a force applied by an object away from another object

pulmonary artery a blood vessel in humans that takes blood from the heart to the lungs

pulmonary vein a blood vessel in humans that returns blood from the lungs to the heart

pulsar a rapidly spinning star that emits pulses of energy

pure substance a substance made up of the same type of particle

purpose of an investigation the reason for conducting an investigation

pushing force a force applied by an object towards another object

pyroclastic describes rock formed from volcanic ash and rock fragments

Q

qualitative data non-numerical information that relates to a quality, type, choice or opinion

quantitative data numerical information that is counted or measured and expressed as numbers

R

radiation the transfer of heat by waves of infrared radiation

radioactive element an element that can produce radioactivity

radiosondes devices carried by balloons that measure altitude, pressure, wind and temperature in the atmosphere

random error a small, variable error caused by slight variations in an instrument or the environment

range a measure of spread calculated by subtracting the smallest number from the largest number in a dataset

raw data data that has not been processed or analysed

reactant a substance used up in a chemical reaction

reaction force a force acting in the opposite direction to the applied force and on the object that exerted the applied force

red blood cell a blood cell that carries oxygen

regional metamorphism rock metamorphism caused by heat and pressure

relative dating putting fossils, rocks or events into the order in which they occurred

reliability how similar the results of the same experiment are

reliable consistent; able to be trusted

renewable energy source a source of energy that can be produced at a faster rate than it can be used

replicable something that can be reproduced or copied exactly

replicated repeated to obtain similar results

repulsive force an indirect force that pushes two objects away from each other

residue what is left in the filter paper after filtration

resolution the finest detail that can be distinguished in an image

results the information gained from an experiment

revolution the path an object travels as it moves around another object

ribosome an organelle that synthesises proteins; the smallest organelle

ridge push the process that moves crust away from a mid-ocean ridge

rift a valley created by rocks being pulled apart

ring barking removing the bark containing phloem from around the trunk of a tree, but leaving the xylem intact

risk assessment an assessment of potential hazards and how to minimise them

risk factor a condition or behaviour that increases the likelihood of a person developing a disease or health disorder

rock a naturally occurring solid made up of minerals

rock cycle a model used to explain how rocks are formed and how they change

root hair a long extension that provides a large surface area for the root of a plant

root system the water- and nutrient-absorbing part of a plant; usually below ground

rotation the motion of an object around an internal axis

rough endoplasmic reticulum (RER) endoplasmic reticulum that produces and transports proteins

row a horizontal division in a table

S

safety data sheet (SDS) a document that provides information about the hazards and risks associated with a substance or material

safety flame the cooler flame from a Bunsen burner that is easily visible because it is orange; also known as the orange flame

saprophyte an organism that digests dead matter before ingesting it; also known as a saprotroph

satellite an object in orbit around a larger object

saturated solution a solution that has the maximum amount of solute dissolved in the solvent

science the study of the natural and physical world by asking questions, making predictions, gathering evidence, solving problems and revising knowledge

science communication talking, raising awareness or even arguing about science-related topics

scientific literature secondary sources of data from scientists; used as references in investigations

scientific model a model based on observations and measurements of an object or process

scientific processes steps involved in working scientifically

scientist a person who uses research to gain knowledge and understanding of any area of science

screw a long, inclined plane wrapped around a solid cylinder

seafloor spreading the theory that new seafloor is created at mid-ocean ridges, spreads outwards and then descends into the mantle at trenches

season a period of time characterised by weather and day length

secondary consumer (second-order consumer) an organism that eats a primary consumer; a carnivore or omnivore

secondary data data that has been collected by someone else

secondary source a publication, information or data that has been written or collected by another person

sediment (in earth science) solid material transported from one place and deposited in another

sediment (in chemistry) the insoluble solid that settles on the bottom of a suspension

sedimentary rocks rocks formed from sediments

sedimentation the process of particles settling on the bottom of the liquid part of a suspension

septum the dividing wall between the left and right sides of the human heart

shell (electron shell) an energy level around the nucleus of an atom containing electrons of the same energy

shoot system the leaves, stems and flowers of a plant; usually above ground

sieve plate holes at each end of a sieve tube cell that allow the passage of sucrose

sieve tube cell a nutrient-conducting cell in a plant that forms phloem

simple machine a device that can increase the size of an applied force

simulate represent different aspects of a phenomenon in a model to make predictions

slab pull the force driving tectonic plate motion caused by a sinking plate

smooth endoplasmic reticulum (SER) endoplasmic reticulum that transports and produces lipids and some carbohydrates

social media technology allowing users to create, publish and share content

solar eclipse when the Moon passes between Earth and the Sun, blocking the view of the Sun from Earth

solar flares eruptions of energy from the surface of the Sun that can cause radio and magnetic effects on Earth

solar power electricity generated directly from sunlight, using solar cells

solar year the time it takes for a planet to revolve once around the Sun

solid a state of matter in which the particles vibrate in fixed positions close to each other

solidification the process of changing from a liquid to a solid

solubility how much of a substance can dissolve in a certain volume of another substance

soluble unable to dissolve in another substance

solute a substance that dissolves in another substance to form a solution

solution a mixture formed when a solute dissolves in a solvent

solvent a substance that dissolves another substance to form a solution

sound energy energy transferred as a wave through or by vibrations

space the three-dimensional region (length, width and height) where an object exists

species a group of similar organisms that can breed to produce fertile offspring

specific name the second part of the scientific name, which identifies the species within a genus

specimen a sample to be examined or observed

sphincter a ring of muscle that can close off a tube

spring balance a device for measuring force; also called a force meter or newton meter

spring tide a high tide caused by the alignment of the Sun, Earth and the Moon

stage a flat platform that supports the slide on a light microscope

stain a dye used to colour specimens for microscopic study

starch a complex carbohydrate found in potatoes and other plants; also a form of glucose storage in plants

state of matter one of the forms in which matter can exist: solid, liquid, gas or plasma

statistic a value derived from a dataset, such as a mean or a maximum value

statistics the mathematical branch of science dealing with the collection, analysis and interpretation of numerical data

stereotype a set idea about something or someone

sterile cannot produce offspring

stimuli things or events that produce a reaction in living things (singular stimulus)

stomata pores on the surfaces of leaves that allow gas exchange (singular: stoma)

structural adaptation a change to a physical feature or structure of a species that makes it better suited to its environment

structural formula a graphic representation that shows the arrangement of atoms in a molecule or compound

structure how something is built or organised

subatomic particle a particle inside an atom, such as a proton, a neutron or an electron

subduction the process in which one oceanic plate sinks beneath another plate at a convergent boundary

subjective based on personal feelings or opinions

sublimation the process of changing from a solid directly to a gas

sucrose the form of sugar transported in the phloem of a plant

sunspots dark spots or patches that appear on the surface of the Sun

supercontinent a continent composed of all or most of Earth's continents

supersaturated solution a solution that contains more solute than is normally able to dissolve in it at a certain temperature

surface tension tension at the surface of a substance caused by attractive forces between particles

suspended hanging or keeping from falling

suspension a mixture of at least one insoluble solid and a liquid or solution, where the insoluble substance settles to the bottom of the container over time

symptom an indication of a disorder or disease

system (in biology) a group of organs that work together to perform a specific function

system (in physics) a collection of objects or items within a boundary



tap root the large tapering main root of some plants

taxa groups in the classification system of organisms (singular: taxon)

taxonomy the study of naming, defining and classifying organisms

temperature how hot or cold something is, measured in degrees Celsius (°C)

tension force a force that acts to pull along a rope, cable, string, wire or chain

tertiary consumer (third-order consumer) an organism that eats a secondary consumer; a carnivore or omnivore

testable question a question that can be answered using scientific processes; it must be relevant and include the selected variables

theory an explanation of why a phenomenon happens

thermal energy energy contained within an object by its vibrating particles, which determines an object's temperature

tidal energy electricity generated from the ebb and flow of the tides

tidal range the difference between the height of high and low tide

tide the regular rise and fall of the surface of the ocean

tilt sloping away from the vertical

time how long something takes, measured in hours (h), minutes (min) and seconds (s)

tissue a collection of cells that have similar structures and functions

total force (net force) the sum of all forces acting on an object

total lunar eclipse when the Moon is in the umbra of Earth's shadow and none of the Moon is easily visible

total solar eclipse when Earth is in the umbra of the Moon's shadow; none of the Sun is visible from Earth

trace fossil a structure or an impression left by a plant or animal, which shows that life existed

trachea a tube that runs from the back of the throat to the bronchi

transdisciplinary scientist a scientist who is trained in knowledge from different branches of science

transfer the movement of something from one place to another

transform boundary the border between two tectonic plates that are sliding past each other

transparent see-through

transpiration the loss of water by evaporation from stomata, mainly from the surface of the leaves

transportation the movement of solid particles by agents of erosion over large distances

transuranic an element that comes after uranium in the periodic table

tree diagram a diagrammatical dichotomous key made by branching, which represents the splitting of each group

trend the general pattern or direction of data

trophic level a level or position in a food chain

tsunami a series of large ocean waves created by an undersea earthquake or volcanic eruption

Tyndall effect when the insoluble particles in a colloid scatter a beam of light, enabling you to see the beam of light

U

umbra the innermost, darkest part of a shadow where the light is completely blocked by an object

unbalanced force a force that does not have an equal force acting on the same object in the opposite direction

unicellular composed of only one cell

unit a fixed quantity used as a standard of measurement

unsaturated solution a solution that can dissolve more solute

uplift the process whereby rocks formed underground are raised to the surface

urea nitrogenous waste that is produced as amino acids are broken down in the human body

ureter the tube that carries urine from the human kidney to the bladder

urethra the tube that carries urine from the bladder to the outside of the human body

urine liquid containing multiple waste products, especially urea

V

vacuole a membrane-bound liquid sac found inside a cell

valence electron an electron in the highest energy shell of an atom

valid investigation an experiment that tests the hypothesis

validity the extent to which an investigation tests a hypothesis

valve a structure in the human heart and veins that prevents backflow of blood

vaporisation the process of forming a gas; evaporation, boiling or sublimation

variable a factor that could influence the result of an investigation

vascular bundle a combined strand of xylem and phloem tissue in plants

vein (in humans) a blood vessel in humans that carries blood to the heart

vein (in plants) a vascular bundle of xylem and phloem tissue in a leaf

vena cava a large vein in humans that brings blood to the heart from all parts of the body

vent the central opening of a volcano

ventricles the two lower chambers in the human heart, which pump blood to either the lungs or the rest of the body

villi small finger-like projections on the walls of the small intestine that increase surface area

viscosity a liquid's resistance to flowing

volcano an opening in Earth's crust, through which molten rock reaches the surface

volume the amount of space occupied, measured in litres (L) or millilitres (mL)

W

waning when the area of the bright surface of the Moon visible from Earth is decreasing

waxing when the area of the bright surface of the Moon visible from Earth is increasing

weathering the breakdown of minerals and rocks at Earth's surface by physical or chemical processes

wedge a triangular-shaped tool tapering to a thin edge that acts as a portable inclined plane

weight the downwards force on an object due to gravity

wet mount a glass slide that holds a specimen in a liquid such as water for viewing under a microscope

wheel and axle a solid rod connected to a wheel

white blood cell a blood cell that is part of the human immune system

wilt to become limp and to droop through loss of water

wind power electricity generated by harnessing the kinetic energy of the wind to drive a turbine

word equation a word summary that shows the reactants and products of a chemical reaction

work energy that is being transferred or transformed

workflow the sequence of tasks used in the processing of data or the creation of something from raw materials

X

xylem plant tissue that transports water and minerals from the roots to the rest of the plant

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